Kirsten Ulsrud

Village-level solar power in practice: Transfer of socio-technical innovations between India and Kenya

Dissertation submitted for the PhD degree in Human Geography

Faculty of Social Sciences
Department of Sociology and Human Geography
University of Oslo

April 2015

Series of dissertations submitted to the
Faculty of Social Sciences, University of Oslo
No. 546

ISSN 1504-3991

Cover: Hanne Baadsgaard Utigard.
Print production: John Grieg AS, Bergen.

Produced in co-operation with Akademika publishing, Oslo.
The thesis is produced by Akademika publishing merely in connection with the
thesis defence. Kindly direct all inquiries regarding the thesis to the copyright
holder or the unit which grants the doctorate.

Table of contents

Tables and figures

Tables

Figures

Acknowledgements

This dissertation research has become possible by the efforts and contributions of many people and organizations. I am deeply grateful, and relieved that the end result can now be presented.

This PhD project is part of the international research project Solar Transitions. With the submission of this dissertation, the last of the project's milestones has been reached, and I thank all the members of the research team for the exciting, challenging and rewarding journey we have travelled together. The funding provided by the Research Council of Norway[1] enabled a research cooperation between practitioners and social scientists from three continents, and this cooperation formed the basis for the work presented here.

Sincere thanks go to my research informants in India and Kenya, who took time to share their knowledge, experiences and views. I am also grateful for the generosity and patience shown by Angshuman Majumder and his colleagues in West Bengal Renewable Energy Agency during data collection in India. Special thanks go to the community of Ikisaya village in Kenya and the staff and board of the Ikisaya Energy Centre. The cooperation with you has been an unforgettable experience. Winnie Muli has played an important role and provided useful assistance during data collection over several years, and Matthews Mwanza has patiently updated me on phone every month.

My main supervisor, professor Harald Rohracher, has provided immensely important and thorough advice during the whole research process, and patiently guided my search for the way forward in the writing process. It was good luck to meet him at a conference some years back. His willingness to start a project cooperation has been helpful for my work for many years, and has been crucial for the writing of this dissertation. My second supervisor, professor Karen O'Brien, has provided very valuable suggestions and a lot of inspiration and moral support, in addition to making the larger Solar Transitions project possible. It has been a privilege to have supervisors who have been able to see and appreciate what I have been trying to do, and helped me to do it better. I am also grateful for the supervisors' willingness to coordinate their advice at important crossroads of my writing process.

I am indebted also to everyone else who have read and commented on draft chapters – Tanja Winther, Charles Muchunku, Henry Gichungi, Debajit Palit, Helene Ahlborg, Marielle Stigum Gleiss, Marianne Mosberg, Bjørnar Sæther, Ragnvald Kalleberg, Knut Ulsrud and Kristin Ulsrud. If I have forgotten anyone, it is not because I have not appreciated their contribution, but because the moment of submitting a PhD may put the brain in a state where important events in the past might be displaced. Thanks to Siri Eriksen, Jonas Sandgren, Akanksha Chaurey, Gathu Kirubi, Wycliffe Mauta, Anjali Saini, Benard Muok, Rahul Sharma, Shadrack Kirui and Wycliffe Amakobe, as well as project team members mentioned above, for the good job done for our joint research project, and for useful inputs for this individual PhD project. I also thank supporters of the Solar Transitions project: Private supporters, DfiD, Givewatts, Kirsten Hoff and Kjersti Thoen. Several master students have linked up to and provided interesting and additional perspectives and I

[1] This dissertation forms part of project number 190138 of the Research Council of Norway.

therefore wish to thank Ragnhild Vognild, Kaja Sannerud Andersen, Vilde Blix Huseby, Marianne Mosberg, Lan Marie Berg and Maria Kristina Stokke. I have also appreciated the cooperation with Centre for Development and Environment (SUM), University of Life Sciences (UMB), African Centre for Technology Studies (ACTS), Camco, TERI and Sweco.

Many individuals as well as my employer have supported me to make it possible to complete the dissertation despite an eye problem that made me dependent on other people to enter my work in digital form. Marianne Mosberg and Dyveke Johnsen have provided decisive support that made it possible for me to finalize despite this funny health problem developed after exaggerated computer work. Hopefully it will remain a rare condition among people, as it is a drawback in a digitalized world. It is anyway fun to think of having written a PhD largely by hand, − like running a cross country race on wooden skis of the old days. Thanks for assistance on typing, formatting, entering of references and making of figures to Maria Kristina Stokke, Jarand Ullestad, Jenny Espelund Hognestad, Mathilde Espelund Hognestad, Kristin Ulsrud, Knut Ulsrud, Kristi-Anna Steiestøl, Lan Marie Nguyen Berg, Bjørg Ulsrud, Hildegund Espelund Ewald, Mari Espelund, Kristen Wanyama and Nan Zou Bakkeli.

The Department of Sociology and Human Geography has provided support and understanding for the unconventional sides of this PhD and the overall Solar Transitions project, and supported its international orientation. It has been a privilege to work amongst all the knowledgeable and engaged people who have their workplace at this department, and I have learned a lot from you. The pep-talks from Marielle Stigum Gleiss, Elin Selboe, Linda Sygna, Heidi Østbø Haugen, Elin Sæther, Emma Arnold and several others have helped me to keep up my spirit and carry on when the work started to feel like there was no end to it. I have also benefited from comments and literature updates provided by people met in seminars, conferences and PhD courses, including course teachers. I also appreciate the funding for additional field work from Nordic Africa Institute and SYLFF Foundation.

To my family and friends, you have been very patient and shown strong understanding for the time I devoted to the overarching Solar Transitions project and to the "writing marathon" of the last few years. Little Gustav has become a half year old without his grandma having changed his diapers even once, but I promise to improve in this regard. Little Edvard, we will do a lot of gardening together this spring, and walk in the forest. My three children Kristin, Øyvind and Knut and their partners have assisted me with everything from Christmas preparations to commenting on chapters. My husband Terje has taken care of many practical tasks at home and never complained about my work habits. He has also been an important supporter and financer. To my parents Margit and Magne Espelund, thank you for showing me that one of the joys in life is to learn, and to practice in order to aquire new skills.

Oslo, April 2015,

Kirsten Ulsrud

Chapter 1: Introduction

Of the approximately 1.2 billion people worldwide who do not have access to electricity, 306 million live in India and 31 million live in Kenya; the two countries selected for this research. The rest live in other Sub-Saharan and Southern Asian countries or are scattered around the world. Sub-Saharan Africa and South Asia constitute 87% of the total (World Bank and IEA 2013). In addition, around one billion people who are counted as having access to electricity only have intermittent access because of unreliable electricity supply.[2] About 85% of the people without electricity access live in rural areas.

Households, businesses and institutions must cope with various problems and hindrances to their economy and quality of life created by a lack of basic electricity services (Wilkins 2002, Winther 2008, World Bank and IEA 2013). For instance, people with no or unreliable access to electricity rely on expensive and low quality lighting by the use of kerosene, candles and dry cell batteries. Importantly, conventional, centralized strategies for increased access to electricity has shortcomings, including the inability to achieve universal access, problems of affordability, distribution losses and lacking reliability (IEA 2011, World Bank and IEA 2013). Decentralized renewable energy solutions have therefore been recognized as necessary in order to provide electricity access to all, both as intermediate and long-term solutions (IEA 2011, GEA 2012, World Bank and IEA 2013, Practical Action 2014). However, stronger efforts are needed to find out how it can be possible to utilize such solutions in practice, in ways that reach a large number of people.

International discussions and reports about global energy, climate and development challenges primarily point to a need for financing, equipment and expertise through technology transfer from developed countries to other parts of the world, i.e. from the "North" to the "South" (Byrne et al. 2011).[3, 4] There is often little attention to the work on off-grid renewable energy supply that is already going on in a number of countries in the South. There is growing expertise in many countries, and renewable energy efforts are carried out by governmental actors, firms that produce, import or sell the technology, NGOs, energy consultancies, researchers in different disciplines, technicians, community groups, individuals and international actors (Chaurey et al. 2004, Byrne 2009, Palit 2013, Ahlborg 2015). This is

[2] United Nations Foundation, http://www.unfoundation.org/what-we-do/issues/energy-and-climate/clean-energy-development.html

[3] Japan, Canada, Australia, New Zealand, USA and Europe are considered as «developed» areas by the United Nations (http://unstats.un.org/unsd/methods/m49/m49regin.htm).

[4] A division of the world into "North" and "South" is a rough division, but nevertheless considered as relevant here. This is because a large number of countries in the "South" group have some similar challenges in providing basic infrastructure to all citizens, and because solutions developed in some of these countries are relevant to learn from for other countries within this large group.

done in parallel with efforts for grid extension and construction of large-scale conventional power plants. One motivation for these efforts, in addition to providing electricity services, is the potential advantage of replacing fossil fuel use in power plants. This could help to reduce fuel expenses and imports by utilizing the abundance of renewable resources available.

Several renewable energy technologies have been used in these efforts, but the solar photovoltaic technology (solar PV) has often been seen as advantageous because the solar resource (i.e. sunlight) is plentiful and widely available. Solar energy experts and businesses are working to increase both off-grid and grid-connected uses of solar PV technology at different scales and levels of implementation, both in India, Kenya and a range of other countries (Jacobson 2007, Byrne 2009, Camblong et al. 2009, Jolly et al. 2012, Bellanca et al. 2013). Village-level power plants and single user systems are the two main options for use of solar power in off-grid areas. Research has so far devoted much less attention to the first than to the second. However, solar power plants at the village level represent a promising option for several reasons. One of the interesting features of village-level models is that they seem able to reach a larger portion of the population in each community than both conventional grid extensions and systems for single users tend to do (Wong 2012, Palit 2013). Such power plants also have the potential to provide other kinds of electricity services than individual solutions, and thereby benefit a community as a whole. Village-level plants can be seen as an intermediate solution between centralized electricity provision and individual solutions for households, small businesses and public organizations lacking access.

Although village-level electricity models are promising, they tend to be difficult to sustain in the long run and to replicate and scale up. One challenge is to enable people without previous technical and administrative backgrounds to operate and maintain these infrastructures. Another challenge is that of providing high quality, flexible, affordable and useful services in combination with economically viable operation and maintenance (Shrank 2008, Huseby 2012, Millinger et al. 2012). Those who work on development of such options for electricity provision learn from their shortcomings and build on their achievements. New knowledge, both practical and academic, on factors that influence people's opportunities to benefit from decentralized options is necessary if a large number of people are to be reached.

In general, efforts for making emerging technologies widely available are not putting enough emphasis on the social aspects of the technologies, their adaptation to and integration in social contexts, and the details of the different ways that the technologies can actually be implemented and used at the local level in different geographical settings (Rohracher 2003, Winther 2008). These aspects have rarely been covered in the literature on village-level power provision or on rural electrification in general (Bhattacharyya 2012, Sovacool 2014). Importantly, energy services comprise complex systems of social and technological components interacting across different scales – socio-technical systems – in any particular setting (Byrne et al. 2011). Thus, in addition to technical knowledge and practitioners' efforts, there are potentials for increased contributions from the social sciences in this field.

Existing examples, whether successful or not, are valuable sources of learning for those who seek societal improvement (Hoogma et al. 2002, Kalleberg 2009). Transfer of social and technological innovations between pioneering activities can assist involved actors to draw on relevant experience in other places and countries. However, technologies and socio-technical configurations developed in a specific geographical context are not likely to be directly transferable to another context (Raven et al. 2008). Some kind of translation is necessary, with attention to the dynamic relations between social and technical dimensions and adaptation to different geographical contexts (Metz et al. 2000, Byrne et al. 2011, Romijn and Caniëls 2011). The social sciences in general and human geography in particular have the potential to contribute to increased understanding of how spatial transfer of innovations might take place in context sensitive ways. Just as local, small-scale energy systems can be designed and implemented in a variety of ways, there can also be a variety of ways to carry out transfer of knowledge on local infrastructure systems between different geographical contexts. Importantly, it matters *how* energy technologies are implemented and integrated in social contexts, and *how* a transfer of knowledge, experience and socio-technical innovations is carried out.

This dissertation research investigates village-level solar power supply in India and explores a transfer and translation of knowledge obtained in India to a new local and national context in Kenya. Solar power supply systems in Indian and Kenyan villages are investigated in terms of how they function in practice and why, including availability and affordability of light and other electricity services for the users, and how the local systems are facilitated and influenced by national framework conditions. By applying a socio-technical systems perspective the study analyzes how such a perspective can be used to better understand the human and social aspects of these technology systems without ignoring the technical and economic aspects. The dissertation further examines how a socio-technical systems perspective can be helpful also in studies of spatial transfer of innovations. Geographical analysis is central in this research, including the role of social contexts for how socio-technical change is shaped, and how it can travel and be "translated".

1.1. Objectives and research questions

This dissertation has two objectives. The first is to contribute to the knowledge on emerging solutions for access to basic electricity services for people who are not being served by conventional extensions of electricity grids. More specifically, the contribution is to provide new insights on social and technical aspects of implementation, sustenance and expansion of village-level solar power supply, which is one of the potential options for providing broader access to electricity. The second objective is to conceptually enhance the understanding of transfer of social and technological innovations between different socio-cultural settings, including how an adaptation or translation of innovations to different social contexts may take place. These two objectives are mutually supportive, as will be shown.

Two sets of research questions guide the analysis, one related to each research objective. Perspectives of several kinds of social actors (individual and collective) are important for answering both sets of questions. A bottom up point of view is important both for understanding the specific examples studied in villages and for understanding how knowledge and experience created in one place can be moved and adapted to another place in a different country. It is also necessary to investigate the role of policies and other framework conditions for what the actors do and what they *can* do. The two sets of research questions are presented and explained below.

1. How can village-level solar power supply systems be designed and implemented in ways that make them well-functioning and viable in the long run, useful for the community members and widely implemented and used?

In short, the question concerns how village-level solar power supply can be socially organized, and will sometimes be referred to in this concise way although the content of the question remains comprehensive. The question is investigated by studying the following, more specific sub-questions:

- How did the Indian and Kenyan cases of village-level solar systems function in practice, and why, and how did the interrelation between social and technical aspects influence their viability and conditions for wider use?
- Which qualities of electricity access were achieved, who were able to use the electricity services, and why?

The research takes into consideration the perspective of the people who use the electricity services at the local level, as well as those who do not use the services. People in poor villages have many problems to deal with in their everyday lives which may or may not interact directly with the lack of electricity services. The individuals who are responsible for the daily operations of village infrastructure are crucial, as will be shown. The whole viability of the system depends on them, and it is therefore important to understand their day-to-day challenges, motivations and their space for being innovative. Moreover, although anchoring the research at the local level, it is also important to take the viewpoint of government actors and others who might find the off-grid renewable energy solutions interesting, but challenging to implement, follow up and scale up. The current and potential role of private sector actors who provide equipment or make investments in the off-grid energy sector is also important to include. Finally, the perspective of those individuals who carry out planning and implementation of the local projects is central. The challenges to fulfill requirements of affordability, accessibility and usefulness of the electricity services on the one hand and long term viability, possibility to expand, replicate or scale up the models on the other hand, are at the core of the research.

The second set of research questions guides the analysis of the transfer process generated between the village-level solar power projects in India and Kenya:

2. How can social and technological innovations on local infrastructure systems be transferred between geographical contexts?

This question is explored through the following sub-questions:

- What were the main characteristics of the process of transferring social and technical (socio-technical) innovations between India and Kenya?
- What were the outcomes and extended consequences of the transfer process, and why?
- How did the differences between the Indian and Kenyan contexts at the local and national level influence the process and its outcomes?

The analysis concerns how social and technological innovations created in one socio-cultural setting are investigated and brought into a different local and national context with similar challenges in infrastructure provision. Important aspects are the social learning processes involved in such "de-contextualization" and "re-contextualization" and the role of "socio-technical experimentation" – practical projects – as part of such transfer processes. The details of stepwise, systematic efforts for transfer carried out by various interested actors are analyzed, looking at what inspires participants, facilitates creativity and innovation and the ability to integrate technologies to local contexts, including people's practices and everyday challenges at the local level. The concepts transfer of innovations and transfer of knowledge and experience are here used interchangeably, and it will be discussed at the end of this monograph what has actually been transferred in the studied example.

1.2. Three interrelated research activities

The research questions are investigated by a research design comprised of three parts with different methodological approaches. The first part is a social science case study of Indian examples of local village-level solar power supply systems, drawing on the rich experiences of people who have planned, implemented, used or in other ways been involved in the power supply. The second part is a long-term social science based action research study for developing, implementing and analyzing a village-level solar power supply system in Kenya, using the research findings from India as inputs. This case study includes research on the national framework conditions in Kenya, mapping of energy needs in the village, and research on people's livelihoods and socio-economic conditions. Moreover, the study includes practical development of ideas and plans for a local electricity supply system, actual implementation, adjustment and improvements, based on research results generated underway. Outcomes and extended consequences are critically monitored and analyzed, including observed attempts to replicate elements of this pilot project in Kenya. The third part is an overarching analysis of the transfer and learning process from the first case to the second. The Indian and Kenyan cases in combination constitute a process of spatial transfer of innovations, which is investigated based on continuous documentation underway.

Table 1 below shows the Indian and Kenyan case studies as well as the overarching analysis of the transfer process, placed on two levels. The research in India and Kenya is placed on the first level, concerning research on village-level solar power provision. The focus is on the substance of the transfer process between the two countries. The research on the transfer process itself is placed on a second level, concerning the process as a whole, its characteristics and how it led to its emerging outcomes. This overarching level of research runs as a thread through the analysis of the Indian and Kenyan cases. The first and second level of research shown in the table correspond with the first and second set of research questions presented above.

Table 1. An overview of the research, placed on two levels.

Level 2: Spatial transfer of innovations	Analyzing the transfer process constituted by the two case studies below (5 years)	
Level 1: Solar power supply in villages	Case study in India (year 1-2)	Action research in Kenya: a) Research and project planning (year 1-3) b) Practical project (year 3-5) c) Monitoring and analysis of outcomes and consequences (year 3-5)

These research activities were shaped by an opportunity to facilitate an actual transfer process and implementation of a practical project in Kenya, and by being part of the activity over a period of five years. There were four main reasons for including action research as part of the research design. Firstly, Kenyan renewable energy actors' interest in studying relevant examples of village solar power supply in India could be combined with my interest in exploring how social scientists' research could play a role in spatial transfer of innovations. Secondly, action research could generate an interesting kind of case, a type of spatial transfer process that would otherwise have been difficult or impossible to find among existing activities for transfer of innovations. Thirdly, action research gave a special opportunity to understand a social phenomenon or process from the inside. Experiencing the process and holding the responsibility for its outcomes, one is likely to gain deeper insights compared to other research approaches (Herr and Anderson 2005, Sæther 2010). As expressed by Patton (2002, p.49): "Understanding comes from trying to put oneself in the other person's shoes, from trying to discern how others think, act, and feel." I tried to put myself in the shoes of practitioners working in the small scale, renewable energy field – as far as possible for somebody based in academia. A fourth reason for using action research was that such research combines social science insights with the insights of other social actors and thereby creates processes of co-generation of knowledge for deliberate social transformation (Kalleberg 2009). Social science led action research is combined with conventional social science research and the analysis considers consequences of the methodological choices.

The type of insights sought required a collaborative research approach. In developing the research group it was important to include people with diverse disciplinary, professional, geographical and cultural backgrounds. This would make it possible to include a range of different aspects of local energy systems, transfer knowledge on a variety of aspects and be able to understand different socio-cultural contexts and national framework conditions. This trans-disciplinary research team worked closely with a local community in Kenya. Close cooperation among people with academic, social science knowledge, those with practical and technical knowledge and those with local knowledge was expected to create fruitful learning. As the initiator of the project (called Solar Transitions), I coordinated the team's research and actions and involved myself in nearly every task that was carried out by others. This gave me an opportunity to understand the details of the challenges met underway and factors influencing the emerging outcomes and consequences.

1.3. Research *on* and *for* social transformation

The research approach is similar to a type of *constructive research design* oriented towards a transformation of existing social realities (Kalleberg 1992, Kalleberg 2009). Such research concerns what social actors *can* and *should* do in order to contribute to social improvement. "The constructive task is to develop insights about feasible alternatives to existing structures, distributions and practices, alternatives that are better than existing ones" (Kalleberg 2009, p. 265). A "better" alternative has to be negotiated and defined in each case, through broad participation and co-production of knowledge between researchers and those involved in or affected by the initiative. The constructive task in this dissertation, according to the objectives and research questions presented above, is to increase the knowledge on *how* local energy systems can be organized in order to be viable and benefit those that need them, and *how* to transfer innovative solutions between places. As a consequence, the research also increases the knowledge on how social science research can contribute directly to actual change processes.

In this research, more weight is put on "can" than on "should", both when it comes to ways of organizing local electricity services and transferring knowledge between contexts. This is because it is seen as fruitful to explore a diversity of strategies adapted to specific situations, and because creativity and inspiration is considered valuable when trying to address global challenges. The dissertation will present options that can be further tested, developed or re-designed in different contexts and circumstances. The research results and practical outcomes although they are normative, can provide examples for other projects rather than becoming "the way to do things" (Raven et al. 2008).

One way of doing constructive research is to ask if there is something to learn from a comparable, existing unit. This is done here by studying examples of how social actors have attempted to improve social situations through implementing local power supply systems in the Sunderban Islands in India. Another way of doing constructive research is to intervene in social reality together with others, with the purpose of improving the studied unit, based on what kinds of changes are seen as useful by people who are involved in or affected by the activity (Kalleberg 1992, Engelstad et al. 2005, Kalleberg 2009). In this research the "studied unit" is energy services for community members in a Kenyan village. The intervention is to actively transfer the findings from the studied examples in India to a different geographical context in Kenya, in order to draw on these when exploring solutions for village-level electricity supply in Kenya.

A constructive analysis is underpinned by an investigation of descriptive and explanatory research questions (constative questions) and prescriptive research questions (critical questions) (Kalleberg 2009). Descriptive and explanatory questions concern how a phenomenon is working – what is going on in the studied unit, and why. Prescriptive research questions are about the value of a subject under study, based on chosen value standards or quality criteria described and justified by the researcher. In this research such critical questions are posed about the local cases in India and Kenya as well as about the transfer process. These sub-questions enable a discussion of the overarching, constructive research questions on what actors can and should do for social transformation. According to Kalleberg (2009) a constructive research question is a combination of constative and critical research questions. When asking about how something *can* be done, this is a constative question for discussing the feasibility of actions. When asking about how something *should* be done, this is a critical question for discussing the desirability of actions based on the chosen value standards (or quality criteria).

The use of action research and trans-disciplinary research gives the opportunity to reflect on the potential of social sciences to support change towards greater equity and sustainability. Social scientists might have a role to play in close collaboration with practitioners in order to suggest and analyze transfer processes and explore models for how to carry them out in ways that inspire social and technological change. The International Social Science Council (ISSC) calls for social science research that can inform action for deliberate transformation of society in light of the urgent global climate change threat and the problems of poverty and inequity. They suggest that social sciences has a responsibility to be innovative and to stimulate creative thinking, to do research for change, and to take the lead in developing a new, integrated, transformative science of global change. Innovative methodological developments are also called for, including trans-disciplinary approaches (Hackmann and St. Clair 2012). This dissertation explores such methods.

Action oriented research approaches are unconventional within human geography and other social science disciplines, although there are diverse traditions of action research as will be mentioned in the chapter on methods (Chapter 4). Various types of action research designs are increasingly used, according to Kindon (2010), Reason and Bradbury (2008), and Chambers (2008). The critique towards action research alleges that it is more focused on the action than on the research results, that it provides subjective analysis, and that it applies disputable criteria for research quality. Action research has also presented challenges for this research, for example creating friction between the responsibility for the practical project on the one hand and the research tasks on the other hand. Criticisms of action research and how problems are addressed in this dissertation are discussed in Chapter 4. However, as in any research, action research earns trustworthiness through the way in which it is conducted and presented (Patton 2002).

1.4. Solar photovoltaic technology in off-grid power provision

Before presenting the theoretical research approach in Chapter 2, this section describes some of the main features of the solar PV technology and the main ways of using it in off-grid areas, in order to assist the understanding of the cases analyzed in this dissertation. A technology specific understanding of socio-technical change is important (Arentzen et al. 2002). A village-level solar photovoltaic (solar PV) system will have different challenges, both social and technical, than for instance a village-level bioenergy system, because the technologies have different characteristics. An off-grid power plant based on bioenergy would require constant availability of biomass or biofuel, for instance. Therefore, one specific technology was selected for this research. At the same time, village-level infrastructure projects led by community members can have many features in common even if they use different technologies, especially on the projects' non-technical (i.e. social) features. Figure 1 below explains some technical features of the solar PV technology. Some typical ways of applying the technology are thereafter described, with emphasis on village-level systems.

Figure 1. The main technical features of the solar PV technology in off-grid applications.

Technical features of the solar PV technology

Solar PV technology (also called solar cell technology) produces electricity from sunlight. Individual solar cells are combined into solar panels, also called modules, of different sizes. Their capacity to generate electricity is measured in Watts (W). The concept Wp is often used about solar PV capacity. It means Watts provided during peak sunshine hours, i.e. under optimal solar conditions for generation of electricity in the solar cells. Several panels can be combined into larger solar arrays. They can be mounted on roofs, on poles or on the ground. In off-grid solar PV systems the power is normally stored and used via batteries. In some cases, the power can be used directly, e.g. in solar water pumping systems. The water can be pumped up during the day and stored in a tank or a dam.

In addition to the solar panels and batteries, an off-grid solar PV system also includes some electronic devices, called balance of system components. A charging controller controls and displays the charging of the batteries from the solar panels and the discharging of the batteries during the use of electricity. If needed, there is also an inverter which transforms direct current (DC) from the solar panels to alternating current (AC). Without an inverter, the solar PV system produces DC current and requires special appliances that can run on DC current. AC current makes it possible to use normal AC appliances, the common type of electric appliances.

1.4.1. Solar mini-grids, charging stations, home systems and lanterns

The potential of village-level power supply, especially solar mini-grids, inspired this research from the outset. Solar PV systems (see the box above) are applied in several ways for households and communities in off-grid areas. There are two main applications at the village or community level. These are solar mini-grids (sometimes called micro-grids if they are very small) and solar charging stations. There are also two main applications at the household or single user level. These are solar home systems and recently also solar lanterns. The most common application of solar PV outside national electricity grids are the individually owned or used systems. Even though this research focuses on the village-level, the analysis sometimes refers to systems for individual users because they are an alternative and a complement to village-level systems.

A solar home system (see photo 2 in Appendix 1) mostly consists of a solar PV module (or sometimes several modules) that charge a battery bank to run DC appliances (CFL and LED lamps, fan, TV, etc.). A charge controller is (or should be) part of the system to protect the battery (Palit 2013). A solar lantern is a portable lighting device using either CFL or LED technology for provision of light (see photo 1 in Appendix 1). The lantern (or lamp) contains a rechargeable battery and necessary electronics (a circuit board, a switch and cables). The lantern has its own, small solar PV module with a cable for charging. Some lamps have a small solar PV module integrated in the lamp itself. In addition to these ways of using the solar PV technology, there are also water pumping systems, institutional systems and systems at mobile operators' towers, and many other uses. These are tailor made for their use when it comes to system sizing and components.

Since individual solar systems are the most common, most of the studies on off-grid application of solar PV technology have analyzed such systems to expand knowledge on their implementation and conditions for wider dissemination (Ulsrud et al. 2011). Even though small solar PV systems are not uncommon any more, there are still various economic, practical, institutional, market-related, political and technical challenges that must be dealt with for such technologies to be widely disseminated and to provide the desired advantages (Chaurey et al. 2004, Chaurey and Kandpal 2006, Jacobson 2007, Corsair and Ley 2008, Kumar et al. 2009, Miller 2009, Urmee and Harries 2009, Chaurey and Kandpal 2010).

Importantly, the challenges and opportunities for village-level/community solar power plants are very different from those of single user-systems. The insights on the use and organization of solar home systems and solar lanterns are therefore only relevant to a limited extent for the understanding of similar aspects of village-level models. The latter are larger systems, designed to serve many consumers, and are owned and operated by actors like organizations, businesses and governments instead of by individual users. The village-level models also differ significantly from the individually owned systems in how the technologies are implemented and operated, the features of the electricity services and how they are delivered. These differences highlight the distinct needs for different social organization including institutional (organizational) frameworks for the systems in local communities (Ulsrud et al. 2011).

Village-level solar PV systems for electricity supply in remote areas are much less common than solar home systems, solar lanterns and other small solar PV systems for buildings without grid-connection. The village-level electricity systems investigated in India as part of this research were solar mini-grids. They were selected because they were seen as promising examples for the future. A solar mini-grid (or micro-grid) is a solar power plant with its own battery bank that supplies electricity through a local, low-voltage electricity grid,[5] providing electricity to consumers in a local community (see photos 3 and 4 in Appendix 1).

[5] They usually supply 220 V, 50 Hz, 3-phase electricity

One of the advantages of these power plants is that they are often designed in order to provide AC power (see the box above), giving the electricity users the convenience of using normal electric appliances, although there are limitations on the size of the loads that can be connected. The ways of using the power depend on the size of the installations and the arrangements for prioritization between different users. One or more operators with relevant training operate and maintain the power supply system. This relieves users from owning and maintaining their own system. Solar mini-grids have been implemented in projects in different states in India, Senegal, Uganda and other countries during the last two decades, and represent a large potential for decentralized electricity provision. However, they are still not widespread. The challenges, opportunities and "success factors" identified in earlier research on village-level systems are presented along with the framework of analysis developed for this research (in Chapter 3).

The other main type of village-level solar PV applications, solar charging stations, also came to play a role in this research, as will be seen in the analysis. A solar charging station is a system which can charge multiple devices, usually lanterns, phones and batteries. Solar PV panels provide electricity for charging these devices, through junction boxes where the devises are plugged in during charging.

1.4.2. Advantages and limitations of solar PV technology

The solar PV technology has many advantages, but also disadvantages and limitations, as will be seen in the case studies. One advantage is the modular nature of the solar panels and other components, which makes the solar PV technology flexible in terms of system size, and well suited for decentralized use at different levels and scales of organization. It can thereby also be gradually expanded to meet growing electricity demand. Another advantage is also the possibility to place solar panels in all kinds of areas, including in or around settlements. A final advantage is the availability of the solar resource is in large parts of the world and that involved actors do not need to purchase and transport fuel to the installations.

A main limitation of the solar PV technology in off-grid applications is related to the use of batteries. The lead-acid batteries have been the most commonly used batteries in solar PV systems in India and Kenya up to now, and have a lifetime of 2-5 years. There are also battery technologies that have longer lifetimes and are more expensive, including lithium-ion batteries, which are used increasingly. The life time of the batteries, especially lead-acid batteries, depends on how they are used. It is important to use solar PV systems for the kinds of electric appliances they are sized for.

The necessity to stay within the limits of the electricity demand that the system is designed for is one of the disadvantages of off-grid solar PV systems. The use of electricity cannot be varied the way it can when somebody is connected to a conventional electricity grid. The systems are often dimensioned very closely to the amount of electricity that will be used on a regular basis, in order to avoid extra investment costs. This means that there is little space for consuming additional electricity on special occasions or for occasionally using larger appliances than what the system is designed for, unless there is a hybrid solution involving a diesel generator, for instance.

The costs of solar PV technology have been gradually reduced, but it is still expensive for the majority of people in un-electrified areas. A typical feature of the solar PV technology is that upfront costs are high, while the operating costs are low. However, the costs of repeated battery replacement should also be included in the operating costs.

1.4.3. Local socio-technical systems with solar PV technology

The paragraphs above have concentrated more on the technical aspects of solar systems than the social. Importantly, as mentioned above, technologies are part of socio-technical systems. This is so even at the micro level of practical use. For solar PV systems or other energy systems at the village/community level, it is easy to observe that such energy systems are in fact socio-technical configurations, because the organizational and operational aspects are so crucial for how they work.

Although some scholars point out that the social and technical elements are inseparable, as will be further explained in Chapter 2 (Williams and Sørensen 2002), it may be useful to describe them separately to illustrate what kinds of elements make up a village-level solar system. Some of the elements are more social than technical and vice versa.

The *technical* elements of a solar power supply system at the village-level have been described above. The *social* elements typically include the kinds of energy services it offers (light, mobile charging, etc.), prices of the services, and the knowledge required to operate and use the technology. Other elements are operational routines, achieved revenue, expenses to cover, for example for replacement of batteries, other maintenance arrangements, training programs, and information strategies. Several kinds of individual or collective actors are involved in such a local system, including those who use the services, and staff operating and maintaining the power plant and delivering services to people and local organizations. These actors develop certain practices and routines in relation to the system. Some people play more central roles than others. The motivation and interests of these people is likely to be important, as well as other intangible factors like trust and leadership styles. As the analysis will show, the technical elements influence the social, and vice versa.

Solar power systems at the village-level will usually have most of these typical elements, but a range of details can differ. As commented by Ahlborg (2012, p. 30), "large scale grid extension projects carried out by the national utility are much the same in all locations, while small-scale, off-grid systems come in all sorts of designs". This is due to the continuous attempts to find good solutions and solve typical challenges. Within off-grid energy systems research and practice there is often talk about "models" for energy provision – business models, delivery models, or models for provision of electricity services (Palit and Chaurey 2011, Bellanca et al. 2013). When the models are presented by various experts, the aspects emphasized vary. Sometimes the focus is mostly on the technical and economic aspects, and in other cases the focus is broader.

The term "model" is used also here, although it might sound like a static and narrow entity. It is used in a broad sense, the way it has been used in the project team. The team's task was to "study a model" in India and "develop a model" in Kenya. The term model includes both the socio-technical configuration of a power supply system (including its social organization), the way it is implemented in a local community, and the way it functions and changes after implementation. A power supply model is thus seen as a dynamic entity, both before, during and after the practical implementation, as becomes clear during the analysis. One reason for calling it a model is that many of the main characteristics of a local energy system remain similar over time despite incremental changes, for instance the technical features of a solar mini-grid model, which defines some of the limitations on its uses. Another reason for calling it a model is that it can provide an example that can be built upon and spread – be a model for new activities even though it changes on the way.

1.5. Structure of the dissertation

This dissertation consists of 9 chapters. After this introduction, *Chapter 2* presents the theoretical approaches used, and explains why a socio-technical systems perspective is relevant for the understanding of local energy systems and transfer of innovations between countries and local contexts. *Chapter 3* combines empirical literature on village-level electricity systems with the theoretical approaches and presents a framework of analysis for the local case studies in India and Kenya, which also contributes to understanding of the transfer process. *Chapter 4* accounts for the methodological choices, data collection and analysis, and reflects on my position as an action researcher. The chapter argues that the involved research might be valuable for the understanding of efforts to initiate social and technological change, and reflects on the influence this role has on the data, the analysis and the findings of this research.

The empirical results are presented in four chapters: one on the Indian case, and three on the Kenyan. These four chapters at the same time describe the transfer process from the Indian to the Kenyan case. Each of the chapters thereby contribute to both levels of research; both solar power supply in villages and transfer of innovations between different geographical areas. *Chapter 5* analyzes the Indian case and thereby also shows what kind of understanding of this example informed the following work in Kenya. Thereafter, *Chapters 6 and 7* describe the process of developing solar provision in a village in Kenya, including factors influencing the process. These chapters thereby also describe the process of transferring and adapting insights from India to Kenya. *Chapter 8* critically analyzes how the Kenyan solar power model functioned and continued to change after implementation, as well as the qualities of the electricity access it provided. It also describes extended consequences in Kenya and discusses their reasons. The chapter thereby shows late phases of the transfer process and scrutinizes its outcomes.

Chapter 9 concludes on the two overarching research questions and a theoretical question identified in Chapter 2. One of the dissertation's key conclusions is that spatial transfer of innovations can and should take place through the creation of vigorous processes of "learning through inspiration", co-design, practical work and deep experiencing, including common struggles to solve difficult and challenging tasks. It suggests that energy practitioners and social scientists can contribute to such creative learning processes by doing research and action together, with close attention to socio-cultural contexts and in careful cooperation with people at the local level who are interested in trying out technological, organizational and economic solutions they see as relevant and suitable for them. The learning, innovation and new knowledge likely to come out of such activities can be built on by a diversity of social actors in the work for universal access to electricity.

Chapter 2: Socio-technical change and spatial transfer of innovations

Technology and society are deeply intertwined, and technological change is inherently a social process. This is the basic understanding that underpins studies of how technology is created and used, and has been convincingly shown in social science studies of technologies during the last decades (Kemp 1994, Rip and Kemp 1998, MacKenzie and Wajcman 1999, Russell and Williams 2002, Rohracher 2003). Society and technology change and develop together – they co-evolve. There is a two-way interaction in the co-evolution processes: society shapes and structures technologies and how they are used, and technologies (and the way they are used in society) shape and structure society in turn (Rohracher 2002, Coenen et al. 2012).

The mutual shaping between technology and society happens at different levels of society. At the micro level there is a mutual adaptation between technology and the way we live – i.e. socio-cultural aspects of our societies and socio-economic conditions (Russell and Williams 2002, Ornetzeder and Rohracher 2005). At higher levels of society there is a mutual adaptation between technology and the way societies and economies are organized. The directions taken by technology at different societal levels are influenced by many factors, including historic contingency, individual creativity, collective ingenuity, economic priorities, cultural values, institutional arrangements, stakeholder negotiation and the exercise of power (Stirling 2008). The social shaping of technologies (and the technological shaping of societies) is therefore not only a social process, but at the same time a political process. People and groups have different opportunities to influence the changes, and are affected differently by the changes.

These insights imply that any strategic effort for technological change, including the solar power projects in India and Kenya, will be a gradual process of integration between technology and everyday life (at home or at work), societal institutions at different levels of society, and different individual and collective actors and their interests. Technologies gradually become integrated and embedded in social contexts in specific places, regions and countries and in daily practices of the users of the technologies (Späth and Rohracher 2012).

In cases when technologies are transferred to other spatial contexts than where they have been developed and used, as in the transfer process between India and Kenya analyzed here, complex processes of integration might be involved. Certainly, research and practice's attention on technological change, including transfer of innovations, must go far beyond focusing on technological models to the role of social context and the different ways the technologies can actually be implemented and used at the local level.

The main theoretical approach chosen in this research is a socio-technical systems perspective, complemented by other approaches to social transformation, renewable energy systems, and technology transfer. This chapter is composed of four main parts that shed light on the two levels of research in the dissertation: The case studies in villages and the analysis of transfer of innovations across spatial contexts. The first part of the chapter explains the concept of socio-technical systems and describes "the multi-level model" on transitions to sustainability. These are seen as useful starting points because they provide an overall picture of how society and technology mutually interact and change, and of factors that affect social actors' attempts to create change.

The second part of the chapter presents various strategies for creating technological change for a sustainable society, as suggested by scholars within the socio-technical systems perspective. These strategies are relevant because the cases analyzed here are examples of different kinds of strategic initiatives in the search for new ways of providing energy services to people, through technologies other than those which currently dominate, and through new ways of using alternative technologies. For instance, the transfer process between India and Kenya was based on a planned strategy. The transfer activity itself, including the implementation of a practical project in Kenya was a process of trying out the strategy and learning about its workings with the aim of developing new ways of using solar PV technology in Kenya.

The third part of the chapter goes deeper into certain kinds of efforts for change, so-called "socio-technical experiments" and grassroots innovations. These are about the details of pioneering practical activities on the ground, carried out by engaged actors who develop alternative solutions that can contribute to sustainability in the future, as the village solar projects exemplify. Both the Indian case and the Kenyan action research project are examples of such activities. This section considers literature on how the activities on the ground can be done in ways that stimulate creativity, learning and innovation. Ways to enhance the social embeddedness of new technologies are important, as well as how to create useful experiences on the desirability of the solutions and for whom they suit.

The fourth and final part of the chapter concentrates on transfer of knowledge and experience between spatial contexts. Scholars within the socio-technical systems perspective have pointed out the importance of this issue, but there has so far been little empirical research on the topic within this academic community (Byrne et al. 2011). This dissertation contributes to such research by analyzing an attempt to transfer a certain kind of energy system from villages in India to villages in Kenya, and by exploring how a socio-technical systems perspective can be used to study such spatial transfer of innovations. The different parts of the chapter include geographical aspects related to social and technological change where relevant.

2.1. Socio-technical systems and transitions to sustainability

Any societal system for provision of energy, food, housing, transport or communication consists of a range of social and technical elements that make up a *socio-technical system*. A socio-technical system can be defined as a configuration of heterogeneous technical and social elements, including technical devices or artefacts, organizational aspects, involved actors and social practices in the implementation and use as well as competences linked to the technologies (Hughes 1983, Bijker and Law 1994, Rohracher 2006). For instance, an electricity system consists of the energy generating technical devices; the actors involved in generation, distribution, market transactions and regulation; the knowledge needed for various kinds of actors; research in different fields; complementary technical devices like electricity meters; institutions such as laws or policies, and so on. Other dimensions of the system are the social practices of the users of electricity and the cultural, symbolic meanings of electricity consumption.[6] Another way of describing the socio-technical systems is that they are systems of actors, technologies and institutions, interdependent and interwoven (Rohracher 2001, Berkhout et al. 2010).

In the long-term perspective, established socio-technical systems change, either incrementally, or sometimes also radically. History has shown that there is potential for alternative, socio-technical systems to develop and eventually replace existing dominant systems. A classic example is the transition from sail ships to steam ships as analyzed by Geels (2002). Another example is the transition from horse carriages to cars as dominant models of transportation, at least in some parts of the world. Such historical socio-technical transitions have inspired the development of *the multi-level perspective* on transitions to sustainability, which is an attempt to understand mechanisms of radical socio-technical change through a heuristic of three interacting levels: the regime, the niche and the landscape, as explained below. The perspective combines ideas from innovation studies, evolutionary economics and sociological perspectives on technological change (Geels 2011).

2.1.1. Established regimes and emerging alternatives

The concept of a socio-technical *regime* is used to describe stabilized, dominating socio-technical systems that fulfill valued social functions, for example mobility, where the current regime is based on the combustion engine for vehicles. The system elements, including social practices have co-evolved over a long time period. Another example is the global energy regime that depends on coal, gas and oil (Unruh 2002). The various elements of a socio-technical regime are reproduced by the routines of a diversity of social actors that represent structures or rules such as favorable institutional arrangements and regulations, lifestyles and users' practices, and various capabilities and competences (Geels 2002, Raven 2005, Smith et al. 2005). Socio-technical regimes evolve over time, but usually only in increments (Geels 2002).

[6] According to Geels (2002) and Smith (2007), a specific socio-technical system can be characterized through a list of seven socio-technical dimensions. These are: (1) guiding principles, (2) technology and infrastructure, (3) industrial structure, (4) user relations and markets, (5) policy and regulations, (6) the knowledge base, and (7) cultural, symbolic meanings underpinning practices.

The perspective follows Giddens on the "duality of social structure" and "structuration" processes (Giddens 1989, Geels 2011, p. 27): "On the one hand, actors enact, instantiate and draw upon rules in concrete actions in local practices; on the other hand, rules configure actors" (Geels 2011, p. 27). Changing regimes in the direction of a normative goal like sustainable development is therefore a complicated process of connecting and synchronizing change processes (Raven 2005). The regimes also embody strong convictions and interests that often lead to reactive forces from established structures (Brown and Vergragt 2008). These can be related to business interests as well as to technological practices, for example habits of exaggerated use of electricity. Inertia and path-dependency is also created by regulations and existing infrastructures (Berkhout et al. 2010). At the same time, "windows of opportunity" are created by the shortcomings of the existing regimes (Perez 2002, Berkhout et al. 2010). An example is the failure of conventional electrification strategies to reach out sufficiently well to the populations in many countries, opening up for development of alternative strategies.

In countries where the conventional electricity system does not reach the whole country, and where far from everybody is connected to the electricity grid even in those areas where the grid exists, the conventional electricity system, seen as the regime, is less stabilized than in countries where the grid reaches nearly everybody (Berkhout et al. 2009, Verbong et al. 2010). However, the regime is still strong compared to emerging alternatives, and is well embedded in governmental organizations, markets, international aid programs and cultural values, and has a strong position in the central areas and modern sectors of the countries. Moreover, even un-electrified areas have their established systems such as supply and use of kerosene for lighting, use of batteries, diesel generators and other solutions for different energy needs. This regime also has its shortcomings, not least in terms of dim light from the kerosene lamps. The widespread need for alternatives may make transitions to new systems faster in such situations, but it depends on the possibility for those who need it to actually get access to suitable, affordable solutions. The majority of people in poor, remote areas in the South still lack the opportunity to benefit from solar PV technology, for instance.

The historical experiences that inspired the multi-level perspective suggest that radical changes in terms of development of new societal (or socio-technical) systems begin within networks of pioneering organizations and users that invest time and resources in improvements of new technology, forming socio-technical *niche* practices on the margins of the regime (Smith 2007). These actors attempt to develop new markets, organizations and institutions and to influence government policy (Raven 2005, Schot and Geels 2008). Such niche activities include practical pilot projects and demonstration projects by actors who wish to promote the technology and enhance its further development (Kemp et al. 1998, Coenen et al. 2010). Within this perspective, pilot and demonstration projects are called *socio-technical experiments* (Hoogma et al. 2002, Berkhout et al. 2010). These are practical activities where alternative technologies are tested in real life settings in order to reveal what problems remain to be solved. If promising technologies for future sustainability do not offer obvious user benefits, implementation might require shielding in terms of changes in economic frame conditions, such as taxes, subsidies and changes in regulatory frameworks. Such changes entail politics and resistance (Geels 2011). Within an emerging socio-technical niche, there is an iterative process of learning from individual projects or experiments, sharing experiences among them, and designing new ones. Markets, regulations and infrastructures may gradually take shape, forming an emerging socio-technical system.

A niche innovation has to survive and develop in the context of strong, established regimes, even though it brings a promising technology that can contribute to environmental sustainability. A range of system elements has to develop around the use of the technical devices including science and technology institutions, professional practices, users practices, problem definitions, and lifestyles (Raven 2005, Smith 2007, Geels 2011). Such development of new socio-technical systems is called *system innovation* or *socio-technical innovation* (Brown and Vergragt 2008, Berkhout et al. 2010). System innovation is much wider than innovation within firms or in R&D laboratories, involving many kinds of actors. It is also wider than the individual socio-technical experiments, as will be further explained. Innovation in general (in firms and organizations) has been defined as "creation of new combinations of existing elements" (Schumpeter 1934, in Soete 2009). Another definition of innovation is to think about new and better ways of doing things and try them out in practice (Fagerberg 2005). These definitions of innovation in general can fit also for the stepwise activities that constitute the larger process of system innovation, if the new combinations and ways of doing things are going deeply into the social domain, including social innovations such as new services or institutions (Ornetzeder and Rohracher 2005). System innovation is a comprehensive social process of radical change, which takes time and involves changes in many parts of society and at several geographical scales (Bridge et al. 2013).

Socio-technical systems at the regime and niche levels and the ways in which they evolve are influenced by broader societal contexts external to the systems, also called the *socio-technical landscape*. Characteristics of the broader "technology-external" societal contexts include macro-economic patterns, environmental problems, political ideologies, wars and societal values. These are deep structural trends that actors at the niche and regime levels cannot influence in the short run (Smith et al. 2005, Berkhout et al. 2010, Geels 2011). The landscape level usually changes very slowly, but dramatic events, such as nuclear accidents or rapidly increasing oil prices, can sometimes lead to rapid changes (Geels 2011).

Socio-technical *transitions* entail large-scale, long-term, deep-structural shifts in hegemonic socio-technical systems, often unfolding in the course of 25-50 years (Coenen et al. 2010, Geels 2010, Grin et al. 2011). The three levels (niche, regime and landscape) interact dynamically as the socio-technical transitions (or regime shifts) unfold. Niche-innovations build up internal momentum, changes at the landscape level create pressure on the regime, and windows of opportunity created by destabilization of the regime makes it possible for the niche-innovations to influence or form regimes (Geels 2011). Successful niches are characterized by diffusion of innovative socio-technical practices and gradual formation of alternative socio-technical systems. This brings about aggregate changes through many small initiatives, enabling constituent projects to grow in scale and attract more participants; and by facilitating translation of niche ideas into mainstream settings (Kemp et al. 1998, Raven 2005, Smith 2007, Seyfang and Haxeltine 2012). Some alternative technology systems never reach the same strong position in society as the dominating systems (Raven 2005).

A difference between historical transitions and current efforts for transitions to more sustainable systems is that the latter are goal oriented and "purposive". The goal is to change society from a state where serious environmental problems are threatening human existence to a state where society does not undermine its natural foundation – it is environmentally sustainable (Raven 2005, Geels 2011). However, researchers still recognize that change does not follow straight and pre-determined directions. The co-evolution of the social and technical is a social process of "negotiation" which involves controversies (Smith and Stirling 2007).

The multi-level perspective on sustainability transitions has been used in many historical case studies on transitions, and in analysis of contemporary and potential future transitions to sustainability, for example in electricity systems (Verbong and Geels 2007, Hofman and Elzen 2010), organic food and sustainable housing (Smith 2007) and bio-gas and co-combustion (Raven 2005). Such studies "explain the ups and downs of 'green' niche-innovations by analyzing the learning processes, network dynamics, and struggles against existing regimes on multiple dimensions" (Geels 2011, p. 29). A challenge for the multi-level perspective is the enormous complexity of the study object. Although it is possible to see clear patterns of long-term change in historical transitions, it is difficult to see patterns from a close view of the contemporary situation, where changes tend to be gradual and patchy (Späth and Rohracher 2012, p. 475). The perspective has sometimes been criticized for lacking focus on the actors in socio-technical change (Smith et al. 2005), while proponents disagree, explaining that the actors are present because the socio-technical changes studied are always enacted by social groups, although they are not always explicitly shown in the analysis (Geels 2011).

The use of solar PV technology is far from being an established, dominating regime for provision of electricity, neither globally nor in specific countries, although the installation of grid-connected solar PV technology globally is rapidly growing, feeding electricity into electricity grids (Hanson 2013). The emergence of the solar PV technology and its use is a gradual, but comprehensive process of system innovation that has already unfolded as a niche activity for several decades, through continuous efforts by engaged actors in different parts of the world (Hanson 2013, Verhees et al. 2013, Smith et al. 2014). However, it still has a long way to go before it contributes to a significant portion of the world's electricity supply or is used in all those places where it might be needed. As typical for emerging systems it also has weak or lacking elements, for example the weaknesses of the complementary battery technology used in off-grid solar electricity supply, as the Indian and Kenyan cases illustrate.

2.1.2. Design of socio-technical systems to be implemented on the ground

This research focuses on the actors' activities on the ground and how they seek to develop ways of making the technology useful in practice, "socio-technical experimentation", according to the concepts explained above. The local solar power supply systems studied in India and Kenya are examples of how emerging socio-technical niche innovations can manifest at the local level. The involved actors attempt to develop replicable, local "socio-technical systems" that can be viable in the long run; both economically, socially, environmentally and in other ways. The actors' possibilities are framed and influenced by a range of factors within or outside their control or direct influence. The notion *room for maneuver* can be defined as the actors' opportunities for and restrictions on creating new combinations and try out new ways of doing things, as will be illustrated in the case studies. The room for maneuver is influenced by the structures described above, the local, socio-cultural context where the technology is used, and other factors external to the local system. The concept of *socio-technical design* can describe the choices, shaping and composition of technical and non-technical elements, for instance making up a way of providing electricity services for members of a community by a village-level electricity model. The creation of a local, socio-technical system in a new place can be a comprehensive process of designing and implementing new combinations of technical, organizational and economic designs. It may also require accessing and building up knowledge, and providing access to equipment and other system elements that may not yet be in place.

A socio-technical systems approach and the multiple levels of niches, regimes and landscapes shed light on different kinds of factors that influence actors' attempts to make a technology useful in practice. In this analysis, the approach helps understanding how the planning, implementation and sustenance of local solar systems in communities may be affected by structures constituted by the niche innovation they are part of (the worldwide solar PV sector and the ongoing work and existing markets for solar PV technology in each country), the regimes of dominating energy systems and their dominant position in society, and by the wider "socio-technical landscape" such as prevalent ideologies, world views and values. The systems thinking also helps understanding what policy makers, industry actors or others can or should do in order to improve the opportunities to apply the technology in certain ways. This way of thinking about systems and multiple levels is also likely to be relevant for understanding how socio-technical innovations may be transferred between geographical contexts. The analysis therefore includes various elements of the socio-technical systems perspective as far as they are found to play a role for the specific cases.

2.1.3. Socio-cultural embedding of technology

Local technology projects and practices are not only embedded in broader processes of system innovation and existing electricity regimes, they are also embedded in various geographical contexts with their own specific history, dynamics, and socio-cultural milieu (Späth and Rohracher 2012). Socio-economic conditions, topography, climate and degree of remoteness from cities and markets may also play a role. Attention to the interaction and integration between technological change and spatial context is therefore important both in socio-technical experimentation in a place, region or city and in strategic efforts to transfer knowledge and experience on technology between geographical areas. Spatial transfer efforts (like the example studied here) are likely to lead to processes of technological and societal adaptations in new places both at the local level, and with linkages to broader societal processes.

Actors and institutions related to a socio-technical niche innovation like solar PV technology operate at different geographical scales and organizational levels, like the individual, household, village, district, region, national and international level. Such levels are not the same as the niche, regime and landscape levels of the multi-level perspective described above. Elements of niches, regimes and socio-technical landscapes may appear at all geographical scales and levels of governance (Späth and Rohracher 2012). Examples related to regimes include the use of fossil fuels at the household or village level and related distribution systems for such fuels on the one hand, and large scale power supply with diesel generators connected to national electricity grids on the other hand, including importation systems and economic interests. The actors involved, both in niches and regimes, can operate at many levels, and social structures related to the systems (for instance policy, regulations and politics linked to the systems) appear and exist at many levels. Not only a regime technology but also a niche technology is supported by actors and institutions at various levels, not least the national and international level, but in less influential and established ways. Even in a specific socio-technical experiment on the ground, niche and regime elements at different levels play a role for the activities at the local level, and constitute framework conditions for the local activity in combination with the local social context, as will be seen in the cases analyzed here.

The current opportunities to get access to equipment, expertise and experience as well as existing organizational and financial models for use of solar PV technology have emerged gradually and illustrate the co-evolution of the social and the technical. The emerging, worldwide solar PV sector consists of a wide variety of elements that both enable and set limits for practical implementation of electricity supply with this technology. These include international manufacturing industries, research and development, markets, education, policies, social practices and meanings. These operate both at the international, national and sub-national levels. However, the existence, strength and qualities of most of the elements vary between places, regions and countries. This is the case for the availability of good quality equipment, their prices, government support, expertise on systems design, installation and maintenance, training and education, actual examples of use, number of users, users' satisfaction, etc. Due to such spatial differentiation, not all potential users of the technology have equal access to existing resources and opportunities (Dewald and Truffer 2012, Bridge et al. 2013). Moreover, the existence of a such opportunities does not automatically lead to local electricity supply systems that work for the users, are viable in the long run, become embedded in local contexts and provide access to technical devices for repair and expansion, advisory services and all the necessary information.

Three principles should guide efforts for social transformations according to Stirling (2009) and Leach et al. (2012). These are "direction, diversity and distribution". The *direction* of change – in terms of the goals and principles that guide efforts for social change – should be openly discussed and actively steered away from unsustainable pathways. The priorities of different groups should be taken into account, and grassroots innovations that draw from local knowledge and experience, as well as social and organizational innovations, are at least as important as advanced science and technology (Leach et al. 2012). *Diversity* in approaches and forms of innovations, social as well as technological, makes it possible to respond to uncertainty and surprise which arises from societal complexity and interactions. Diversity provides a "richer resource to foster more robust and resilient innovation pathways into the future" (Leach et al. 2012, p. 4). Diversity is also important in order to find approaches that suit in different cultural and ecological settings. *Distribution* between different people should be kept at center stage – "asking who wins and who loses from particular policies and innovations" (Leach et al. 2012, p. 4). Grassroots innovations can help to prioritize the interests of the most marginal groups. These principles have similarities with some of the ideas underlying the action research analyzed here, as will be seen in later chapters.

2.2. Strategies for socio-technical innovation

Engaged actors' creativity, experimentation and learning influences, but does not determine the gradual development and shaping of socio-technical systems. This section looks at how social actors deliberately create change and how such activities can be analyzed. Activities that contribute to system innovation are parts of long-term processes, consisting of involved individual and collective actions. The outcomes are uncertain and influenced by a large number of factors. Efforts for system innovation can be seen as a way of trying to stimulate and influence the complex processes of co-evolution of the social and the technical for promotion of sustainable socio-technical systems.

Some specific strategies for system innovation are based on the transitions literature, of which strategic niche management has received the most attention (Schot et al. 1994, Hoogma et al. 2002, Raven 2005). These include implementation of practical projects (socio-technical experiments). The strategies aim to facilitate learning processes on social and technological dimensions in order to create radical changes (transitions), and to deal with unfolding transitions' uncertainty, governance, and meaning of sustainability. Grassroots innovation is another kind of experimental activity that contributes to socio-technical change, as will be explained below. Before exploring specific strategies for system innovation, the next section discusses uncertainties inherent in innovation processes due to the open and unpredictable nature of human societies.

2.2.1. Unintended, unexpected outcomes of efforts for change

Purposeful system innovation is needed because of the lack of environmental and social sustainability of current systems for provision of electricity and other societal systems. It is also being done by a large number of actors. However, as much as actors want to shape change, the outcomes of strategies for technological change cannot be fully known during the planning process. The perspective of "social shaping of technology" acknowledges the role of intention, interest and responsibility in innovation, while at the same time emphasizing the emergent and unpredictable nature of socio-technical change (Russell and Williams 2002). It represents a critique of linear models of innovation, for example sequential stages like "invention, development, design, testing, refinement, implementation and diffusion" (Russell and Williams 2002, p. 55). Rather, innovation processes have been shown to be overlapping, interactive, and non-linear (Stirling 2008). Technologies are produced and used in a particular social context by a variety of social actors, influenced by a diversity of social situations and structures. Technologies have widely varying characteristics, strongly affected by interdependencies and feedback between elements of systems they constitute.

Even though there is always choice involved in socio-technical change, technological and social changes "are never fully planned and predicted; they are subject to frequent setbacks and failures and emerge in the course of local struggles to produce a working technology and accommodate it in its use setting" (Russell and Williams 2002, p. 51). Therefore, this research looks at the differences between the intended socio-technical designs for the village infrastructures and the ways they could come to work in practice and change over months and years.

Agency in socio-technical change has to be seen in light of this complexity. The multi-level perspective mentioned above acknowledges the dynamic interaction between structure and agency in socio-technical change processes, as mentioned. These processes involve multiple actors, and display co-evolutionary and emergent dynamics that proceed despite various forms of path-dependency and lock-in. Therefore, governance of such processes, to the extent it is possible, must necessarily take an adaptive and reflexive form (Hoogma et al. 2002, Kemp et al. 2005, Shove and Walker 2010).

The kinds of actors involved in socio-technical innovation include civil society, government, non-governmental organizations (NGOs), companies, knowledge institutes, and consultants (Wieczorek and Hekkert 2012). These actors can play a variety of roles, and their interests stem from environmental concerns, business interests, practical users' interests, research interests and other motivational factors. The engagement of different actors is also influenced by changing needs, values and debates in wider civil society, changing livelihoods and other developments at the socio-technical landscape level (Smith et al. 2005, Smith 2007, Späth and Rohracher 2012).

The challenge for strategic agents is to make transition dynamics and its associated political dynamics reinforce each other sufficiently, in order to gradually tilt the balance of power and legitimacy between incumbent and sustainable practices. This is a diffuse, distributed process that may lead to convergence through common ideas and visions or through the gradual, self-reinforcing structuring of practices. The power embodied in the regimes will privilege particular practices over others (Grin et al. 2011). For instance, political and economic actors and interests may be entangled (Meadowcroft 2011). The following sections consider various ways of promoting radical socio-technical change in the midst of the uncertainty, unpredictability and dynamic interactions mentioned above.

2.2.2. Strategic niche management and processes of niche emergence

Strategic niche management is both a strategy suggestion and an analytical framework related to the multi-level perspective. As a strategy it suggests ways of governing the creation of protective spaces – niches – for socio-technical experimentation and system innovation. As an analytical framework it provides concepts for analyzing processes of niche development and interaction between niches and regimes, which can inform practice on how niches can be strengthened (Raven 2005).

The goal of strategic niche management is to actively create and manage technology niches for radical innovations that can lead society towards transitions to sustainability (Schot et al. 1994, Rip and Kemp 1998, Hoogma et al. 2002, Raven 2005). Recognizing that regime shifts cannot be managed, only modulated, policies of strategic niche management have been suggested to be dynamic, reflexive and open-ended, by observing and modulating the direction of ongoing processes of co-evolution and the directions of search for sustainable solutions (Hoogma et al. 2002, Brown et al. 2003, Kemp et al. 2005). Learning and adaptation are central, through probe and learn strategies, not only for those who engage in practical experimentation, but also for policy makers and other relevant actors. Outcomes of socio-technical experiments are seen as important for fine-tuning policies, and niche management policies are seen as an important supplement to experiments. Such policies include proper governmental regulation and creative application of tax, subsidies and regulatory instruments. Formation of actor cooperation such as public-private partnerships in the implementation, financing and operation of technology projects is promoted (Schot et al. 1994, Hoogma et al. 2002, Kemp et al. 2005, Smith et al. 2014). Interactions and conflicts between new, emerging systems and the established and dominating socio-technical regimes must be dealt with (Raven 2005).

Niche theory and the multi-level perspective in general views socio-technical experimentation in niches as a form of variation and selection of innovations, based on concepts from evolutionary economics. Change is based on the continuous creation of new ideas, technologies, and social arrangements. Some of these variations will survive and grow because they are selected by their surroundings – the selection environment (Brown et al. 2003, Smith and Raven 2012). The selection environment is constituted by the social context – markets, policies, ideas, interests, users' practices, symbolic meaning, and other elements related to dominating regimes. The variation and selection is called quasi-evolutionary because the selection environment is partly known and anticipated by those who generate the variations, and they might also attempt to change the selection environment. Only a small fraction of experiments (variations) likely succeed (selection). Accordingly, only a few of the ways of organizing solar power supply that have been developed and tried out are likely to be part of future regimes for energy supply. For example, after many attempts to make community level solar systems work, it might be seen that simpler, large scale, grid connected solar systems become the norm, perhaps in combination with private ownership of solar systems.

Three kinds of processes are seen as important in "nurturing" socio-technical innovation in niches: managing expectations, building social networks, and learning (Kemp et al. 1998, Raven 2005). Firstly, various actors' *expectations* to what a technological niche can offer society for the future are important for the ways in which they choose to involve themselves in relation to the niche. Expectations, for example to the future importance of solar technology, depend on how a niche is made to look by niche actors, and whether the niche lives up to the promises it makes about performance and effectiveness of societal functions, for instance reliable and affordable electricity supply. To support the development of niche innovation, expectations should ideally be widely shared, specific, and credible (Seyfang and Haxeltine 2012). Expectations become credible if they are substantiated by many projects (Schot and Geels 2008, Smith et al. 2014). Secondly, *network building* is important for niche formation and learning. Networks supporting emerging niche technologies should include a diversity of actors so that these can bring in resources from their various organizations. Thirdly, *learning processes* should be created on a broad range of social and technological aspects and include second order learning, which is explained below (Kemp et al. 1998, Schot and Geels 2008, Seyfang and Haxeltine 2012, Smith et al. 2014). The learning processes are the most important and most comprehensive of these three, as will be explained further.

The concepts of shielding and empowering the niche have been suggested as additions to these three concepts of nurturing (Smith and Raven 2012). *Shielding* refers to the processes of creating protective space, reducing the "selection pressure" from the regime. Shielding may be created by active introduction of innovation-specific public or private interventions, or pre-existing situations like market niches, where there are few other alternatives available. An example of the latter is geographical areas outside the reach of centralized electricity grids where solar PV technology has met less competition than in areas with grid electricity available. The protective spaces allow the niche innovations to be nurtured and further developed (Smith and Raven 2012). In their analysis of the niche spaces for solar photovoltaic electricity in the UK, Smith et al. (2014) suggest that both discursive and material activities play a role in negotiation and compromises involved in creation of spaces for sustainable innovation. This includes a collective process of developing appealing narratives about the technological performance and opportunities for the future (Smith 2007, Smith et al. 2014).

Empowering takes two forms (Smith and Raven 2012). The first form of empowerment makes the niche innovation, such as solar PV technology, competitive under existing selection environments. An example of such empowerment is the rapid reductions in prices of solar PV modules during the recent years, improved production processes, economies of scale, and learning in the installation of the solar PV systems, and also improved solar PV module designs (Smith et al. 2014). This is called "fit and conform" to the selection environment. The second form of empowerment reforms regime elements (the selection environment) to become more favourable to the niche innovations. This is a result of niche actors' lobbying in "the wider social world" in contrast with inward oriented accumulation of technology across networks of projects (Smith and Raven 2012). One example is the ways in which solar PV advocates have been able to influence policies, for instance the German implementation of the feed-in tariff. This is referred to "stretching and transforming" the regime/selection environment. The first form works on the "content of innovation", and the second on the "context of innovation" (Smith et al. 2014).

This dissertation is not a typical niche analysis, although it considers strategic efforts within niches and their outcomes. Nevertheless, the cases analyzed here show examples of various niche processes, and demonstrate ways in which they can be stimulated. Specifically, the cases show examples of vigorous processes of learning and socio-technical innovation at the project level and beyond, and goes in detail on which activity "ingredients" are important for such learning, including the role of transfer of knowledge between projects in different countries. The various concepts for niche analysis will be referred to when relevant examples are described, but they will not represent the main analytical framework.

2.3. Which factors facilitate learning and innovation in socio-technical experiments?

As mentioned before, the cases analyzed here can be seen as cases of socio-technical experimentation – an activity of trying out new ways of doing things and learning from this. This section considers two types of socio-technical experiments: "sustainability experiments" (Berkhout et al. 2010) and "bounded socio-technical experiments" (Brown and Vergragt 2008), shows their relevance for this research, and identifies literature on how the experiments' design influence their achievements. In addition, section 2.3.2 presents so-called grassroots innovation which can also be seen as a type of socio-technical experiment.

2.3.1. Types of socio-technical experiments

The concept of *sustainability experiments* is used to describe pilot and demonstration projects undertaken by various societal actors, involving socio-technical configurations likely to lead to substantial sustainability gains (Berkhout et al. 2010). Examples include off-grid renewable energy projects carried out by firms, governments, local groups and others. The Indian case studied here is such a project. The Kenyan case has similarities with this and other kinds of socio-technical experiments and grassroots innovations, as will be explained in the analysis. Some sustainability experiments are created in order to demonstrate for potential users how the innovations may work for them, other experiments aim to stimulate policy making or assess the feasibility and suitability of innovations in new environments (Raven 2005). Such projects, carried out by pioneering actors, existed long before theories on transitions and niche management were formulated and have continued more or less independently of these ideas, although some experiments and policy making have built on these perspectives (Loorbach and Rotmans 2010).

The literature also describes *bounded socio-technical experiments,* meaning small-scale experiments aimed at developing, testing and introducing new technologies and services on a scale bounded in space and time (Brown and Vergragt 2008). The time dimension is a few years, and the space dimension is defined either geographically, i.e. a community, or by the number of users, which is small. The participants are coalitions of actors, including businesses, governments, technical experts, educational and research institutions, NGOs and others. One of the participants acts as an analyst who monitors and analyzes the process and its outcomes. Its goal is to "try out innovative approaches for solving larger societal problems of unsustainable technologies and services" (Brown and Vergragt 2008, p. 112). As will be discussed in the analysis, the Kenyan case has similarities with such an experiment.

A bounded socio-technical experiment differs from a strictly market driven introduction of new technologies and services, like introduction of an electric car, or solving a particular environmental problem in a community, such as alleviating pollution through traffic control. As with other kinds of experiments, it can represent a means of testing the feasibility of new technologies or services before they are ready to enter the open market (Brown and Vergragt 2008). The emphasis is on the learning processes for the team members and the team as a whole, and on diffusion of the learning to actors outside the experiments.

2.3.2. Grassroots innovation and its similarities with socio-technical experimentation

Another type of activity with the potential to identify pathways towards sustainable futures is grassroots innovations. These are relevant for this analysis because there are certain similarities between such innovations and the solar energy cases. Grassroots innovations have similarities with socio-technical experiments, but also several differences. Committed networks of activists and organizations in civil society[7] attempt to generate novel bottom-up solutions for sustainable development by "experimenting with social innovations as well as using greener technologies" (Seyfang and Smith 2007, p. 585).

Community led sustainable energy projects are one type of grassroots innovation. These involve local groups "developing sustainable energy solutions appropriate to local situations, and with community groups having ownership over outcomes" (Smith 2012). In the UK for instance, numerous community-led sustainable energy projects have received support from government programs.[8] Examples include co-operatively owned small-scale renewable energy systems, such as biofuel projects, micro-hydro projects and community owned wind farms. The approaches taken by the different groups are multi-faceted and bridge energy production and consumption in a variety of ways. Other examples of grassroots innovations are local food projects, furniture-recycling schemes, and new energy related consumption practices (Seyfang and Smith 2007, Hielscher et al. 2011, Seyfang and Haxeltine 2012).

Community projects are multiple, and can realize ideas that top-down policy instruments cannot achieve. The bottom-up projects involve local knowledge and engagement and creation of social capital and trust among local actors (Hielscher et al. 2011). Such activities can be seen as a type of niche experiments by civil society, because they help to explore alternative ways of fulfilling social functions such as providing food, housing, mobility/transport and energy (Smith 2012) argues that grassroots innovation, with their "sheer variety and fluidity of civil society forms, activities and consequences", may play a role in both unsettling and destabilizing unsustainable regimes, and in nurturing and empowering sustainable niches. They can also provide solutions to translate from niches to mainstream settings. Seyfang and Haxeltine (2012) demonstrate that the multi-level perspective and niche theory can be used in order to understand grassroots innovations and their role for future sustainability. Grassroots innovation focuses on how equity and quality of life can be enhanced as part of the work on environmental sustainability, and may contribute to a fruitful diversity in innovative options for the future (Smith 2012). This corresponds with the call for more equitable distribution and more diversity mentioned earlier (Stirling 2009, Leach et al. 2012).

An important feature of grassroots innovation is that it operates within the so-called social economy of community activities and social enterprise. In contrast, the literature on socio-technical experiments and strategic niche management primarily deals with niches of

[7] Smith (2012) broadly describes civil society as "… an arena that encompasses the collective activities by which associations of people develop and assert shared values, identities and interests, without direct recourse to market transactions or the authority of the state in the first instance."

[8] More than 500 community renewable energy projects were identified in the UK by Walker et al. (2007).

technological innovations developing within commercial markets (Raven 2005, Seyfang and Haxeltine 2012). Grassroots innovations therefore differ from technological, market-oriented niches in several ways (Seyfang and Smith 2007). Within the social economy, any surplus is re-invested into the grassroots instead of giving profit to private companies. An example of this will be seen in the Kenyan solar energy case of this dissertation. The driving force for conventional innovations is profit. For grassroots innovation motivations include social need as well as ideological commitment to alternative ways of doing things (Seyfang and Smith 2007). The organizational form typical in market-based innovations is the firm, while a range of organizational types are connected to grassroots innovation, including voluntary associations, co-ops, and informal community groups. There are also differences in the resource base. Market-based innovations are mainly financed by income from commercial activity, while grassroots innovations are financed by grant funding, voluntary input, mutual exchanges, and limited commercial activity (Seyfang and Smith 2007).

> The social economy provides flexible, localized services in situations where the market cannot. Incumbent production and consumption systems fail some communities, perhaps because groups are socially and economically disadvantaged, unable to access goods, services and markets, or because market choices do not extend to sustainability, such as fresh, local organic food in season, or autonomous housing, or community renewable energy (Seyfang and Smith 2007, p. 591-592).

Despite the value-based activities, grassroots innovation should not be romanticized. Grassroots participants might sometimes find themselves in a niche for consumption because of social and economic exclusion, and might wish to have access to the mainstream type of consumption (Seyfang and Smith 2007). This might be the case where infrastructure is poorly developed. Despite their environmental and social advantages, alternative solutions such as solar PV systems might not fulfill people's needs as well as mainstream (regime) solutions. It *might* nevertheless be possible to make the alternative solutions work better than the mainstream in terms of broad access, social equity, and human well-being.

2.3.3. How should the experiment be organized to create learning?

In the gradual process of deep transformations, individual socio-technical experiments or clusters of experiments might look like drops in the ocean. However, without attempts to create practical change and develop potential socio-technical configurations for the future, basic building blocks for long-term changes would be missing. Experimentation is at the core of socio-technical change (Geels 2002, Raven 2005, Smith 2007, Schot and Geels 2008, Seyfang and Haxeltine 2012). They are important even though they often lead to outcomes far from the high visions of the people who created them. More often than not, an innovative project ends up becoming just an experiment that was never scaled up (Brown et al. 2003). Involved actors struggle to solve problems, often without succeeding in the end. As commented by Hoogma et al. (2002): "Something always tends to go wrong in these experiments". Moreover, even if the project itself works out well, the project may not be replicated, for various reasons. However, as argued by Brown et al. (2003) an unsuccessful experiment is not a wasted effort, because the outcomes in terms of learning, exploration, and trying out options are nevertheless important. This holds despite the setbacks that often follow unfulfilled expectations about the usefulness of a technology (Geels and Raven 2006).

Although experiments are useful even when they do not achieve participants' visions, and since failure entails some risk, it might be important to have a closer look at how the experiments can be designed and organized in order to create as vigorous learning processes and useful outcomes as possible. Learning and innovation are central processes in system building. This is more or less what practical experimentation is all about for involved actors – it is the comprehensive, time-consuming work that they do over years in order to address their challenges. It is therefore important to increase the knowledge on *how* the learning processes within experiments occur – under what conditions and by what dynamics they are created – and how their outcomes are shaped (Brown and Vergragt 2008). Vital and dynamic learning processes are likely to make a project more innovative and better embedded in social life. For instance, it is likely that a project can work better for the social groups that it affects, and have better socio-economic impacts, if it is based on thorough, common socio-technical learning. The chance for replication may also increase from good learning on what specifically can and should be replicated. Documentation and analysis of how and under which conditions experiments' learning processes unfold and which societal impacts they have, and how they diffuse out of the experiments are therefore important (Brown and Vergragt 2008).

Research on socio-technical experiments often represents a bottom-up view of socio-technical change. However, the transitions literature on niche development has been critical about its own focus on changes from the bottom up (Coenen et al. 2010, Geels 2011, Smith and Raven 2012). Some researchers call for taking a step outwards from bottom-up studies of niche internal processes to also consider how niches' protective spaces are created and negotiated by niche actors as mentioned above (Smith and Raven 2012, Smith et al. 2014).

Although this step outwards is important, it might also be important to take a step further inwards than what niche analysis usually does. One could step down from the niche level to have a closer look at what is going on *inside* the individual experiments and pioneering activities on the ground and what this might mean for the outcomes. Importantly, an experiment is not the same as a niche (Raven 2005). The unit of analysis in niche studies is usually the dynamics of niches, and not the single experiment. The experiments are seen as entry points to create niches, but do not receive much attention in the analysis (Romijn et al. 2010). Therefore, the following paragraphs present ideas and suggestions on how socio-technical experimentation can be designed or organized in order to enhance learning and innovation.

Details of how the experiments can be organized in order to facilitate vigorous, creative learning processes are related to a range of different aspects. These include the kind of activities done, the composition of teams, leadership and ways of cooperating, the process steps (research, practice, dissemination, follow-up), shaping of the new socio-technical design to be tried out in practice, and interaction with people outside the group. Although there are only few contributions in the literature on experiments' details, the topic is mentioned by various authors.

One recommendation for the initial experiment planning is that the choice of experiments should be based on how they may add up to the emergence of the niche and how they exploit instabilities in dominant socio-technical regimes. This requires analysis of the niche systems and regime (Hoogma et al. 2002, Loorbach 2007). There are more recommendations on *what* the experiments can and should do, but fewer on *how* they can do it. For example, it has been stated that the experiments should exploit the co-evolutionary nature of technology, "working on both the technical *and* the social side in a simultaneous and coherent manner" (Hoogma et al. 2002, p. 3). The trying and learning should go beyond technical learning; and involve learning about user needs, societal benefits and negative effects, as well as regulation.

A recommendation on *how* to achieve such features of experiments is to emphasize the social side of the project, and the users' perspectives. Many experiments, including renewable energy projects in the South often overemphasize the technologies and technical improvement, and lack follow-up after the project (Palit and Hazarika 2002, Kumar et al. 2009). Moreover, the key aim of an experiment should be learning, not quantitative goals like how many technical devices would be installed or applied (Hoogma et al. 2002). A tendency of the latter has been observed within the empirical field studied here, in reports from governments and presentations by international organizations. Another recommendation for the experiments is that learning by doing or a "probe and learn" strategy makes a project flexible and gives an opportunity to react to project outcomes and various changes relevant to the project. A phased approach and adaptive strategy facilitates an emergent process, giving the experiment an emergent rather than deliberate character (Brown et al. 2003, Raven 2007). Continuous course adjustments should be done on the way, through sequential decision-making. Goal-setting can be an ongoing, evolving activity.

A common recommendation for socio-technical experiments is that there should be strong, guiding visions for positive outcomes. A sense of urgency among the participants can also be important for their engagement. Although it is important to have committed partners or team members, they should have balanced ambitions. Brown and Vergragt (2008) suggest that project partners' expectations should be articulated continuously in order to ensure good cooperation. Another recommendation is that the participants should be mixed, and form a heterogeneous group of actors in terms of representing different organizations, communities of practice and institutional affiliation. There should not only be niche actors, but also regime actors, although niche actors should be in majority numbers (Loorbach and Rotmans 2010) A mixed team is assumed to include a variation in perspectives and worldviews, and ways of interpreting the situation and the emerging outcomes of the process. Different perspectives on a problem can enhance the understanding of it and broaden the range of available solutions (Brown and Vergragt 2008).

There might be a tension between, on the one hand, having group members with differing backgrounds and, on the other hand, working intensely and closely together to solve challenging, real life tasks and explore new ground together. This demands a style of leadership that can reduce this tension (Loorbach and Rotmans 2010). Team leaders should encourage understanding and learning between actors with different motivations (e.g. representing niches and regimes) (Avelino 2009). However, disagreements are also valuable. Discussions, negotiation and congruence on problem definitions are necessary. Team members such as social scientists and technical experts may have to collaborate in order to reach solutions. A point related to leadership is also that managing disappointment may be important, since the experiment may be a persistent struggle to solve unexpected problems. Painful times are common – and failure might prove to be inevitable. The team needs repeated encouragement for self-reflection, and reassurances. This leads to repeated trying, failing and learning (Brown and Vergragt 2008). Interactive processes are seen as important, both between team members, and between people and technology. Another point related to leadership in projects that involve such challenging processes is that the leaders should have a strong, intrinsic motivation for the work (Avelino 2009).

Distinguishing between first and second order learning (or lower and higher order learning) is often emphasized (Raven 2005, Coenen et al. 2010). Learning can be defined as an interactive process of obtaining new knowledge, competences or norms and values (Nevens et al. 2013). In second order learning, people question the assumptions about a social function (such as mobility) and the constraints of regime systems, and how a social function can be organized in new ways (Kemp et al. 1998). Such learning is seen as necessary for a range of actors, from individuals to professional and business communities. In contrast, first order learning is "problem solving" only, which entails applying tools that the participants have for addressing a previously defined problem, such as engineering analysis, cost-benefit analysis and risk analysis. Learning at this level does not involve reflections on the objectives of the project, or questioning the match between the social problem and the solutions that the particular technology represents. Nevertheless, while the purpose of doing experiments is to contribute to radical transitions and transformation, learning within the experiment is necessarily incremental (Brown and Vergragt 2008).

2.3.4. User innovations and the role of social practices in social learning processes

A part of the socio-technical systems perspective explicitly deals with user innovations and social learning processes at the micro level. This is an important part of how socio-technical experimentation can be organized in order to facilitate the kinds of learning processes needed. Transition theory has been criticized for focusing too much on supply-side actors (corporate, technology and policy actors) of societal functions such as electricity supply, while key demand-side actors (in particular consumers) are largely neglected (Shove and Walker 2010, Grin et al. 2011). Users of technology can and should play an important role as participants in socio-technical innovation processes (Ornetzeder and Rohracher 2005). This insight is relevant for designing, implementing and following up socio-technical experiments in ways that facilitate learning on how technology can be designed to become as useful as possible for the people. Learning is needed on how technology can be made to fit with their needs, practices and interests.

Technology users can be different kinds of actors. In a local solar electricity system they can be those operating the system, people who are using the electricity services, managers, or others who relate to the system. So-called intermediary actors (f. ex. civil society organizations, research organizations, implementers of technology projects, or advisors) also play a role in shaping the ways in which technologies are used and adapted to socio-cultural contexts. They also have an impact on users' chances of influencing the process (Rohracher 2009).

The concept of technology appropriation is also relevant for socio-technical experiments. This refers to users' active participation in negotiating meanings related to a thing (artefact, technical equipment). Use of technologies is not clear when they enter a social context (Sørensen 2013). According to Shove (2001, p. 265, in Ornetzeder and Rohracher 2005, p. 4): "Understandings of need, normality and value do not just arise, they are forged in the context of already rather developed social, political and commercial settings." Only through practical engagement with the technology can one know how it can be used and under which conditions (Ornetzeder and Rohracher 2005). Technologies and the ways people use them are not static – they are shaped by a range of societal aspects. Technologies are malleable and there are always choices involved, both in their use and the continuous development of their design. One example is the ongoing change in lighting technology such as CFL lights, LED lights, and diodes. Factors such as energy efficiencies, aesthetics, costs and other characteristics influence the users' choices and further developments. Technologies in turn open up possibilities for new social practices and ways of life, for example when somebody gets electric light for the first time. However, the potential for dynamic and reinforcing effects of creative use is often overlooked in studies of technology deployment (Sørensen 2013).

A case study on energy efficient buildings in Austria illustrates the necessity for project implementers to be aware of the complexities involved in introducing a new technology among its future users, and the importance of providing sufficient time and attention for learning and appropriation processes by all involved people. Mismatches between people's daily practices and the new solutions for energy efficiency, such as a wish to open the windows despite having highly efficient ventilation systems, require negotiations, adjustments and technical improvements. Moreover, sufficient time and room for maneuver also has to be provided for the establishment of new practices and related learning processes. Measures that enhance learning processes can help to systematically analyze the difficulties that typically occur during the implementation of technology projects. It is also important to analyze users' experiences after project start-up, and support and advice should be given to users while the technology is still new to them. Users' experiences of implementation and use produces tacit knowledge among all the involved actors, and part of this tacit knowledge can be accessed through facilitating interaction and communication between users, implementers, suppliers and others (Ornetzeder and Rohracher 2005).

A further point with relevance for how technology projects' (socio-technical experiments') organization creates fruitful learning process is that social practices, embedded in culture, economy and society, influence the way people choose to use a technology or engage with an emerging socio-technical system. A range of factors, such as food culture and home and life values influence social practices (Winther 2005, Wilhite 2008). These practices and social structures are also transformed during the adoption and appropriation of technology. Both the "social shaping of technology, and the "technological shaping of society" can to some extent be directly observed at the local/micro level, in terms of the limitations and opportunities given by the technology.

2.3.5. How can the lessons be spread from the practical projects?

People who attempt to develop good models for alternative energy systems or in other ways try to contribute to activities of system innovation through practical projects will in most cases have a vision that the model can be replicated or up-scaled in the future. This might not happen, but socio-technical experiments might result in different kinds of outcomes. These might contribute in small ways towards larger changes and potential transitions.

The literature provides some insights in how learning generated within the experiment may diffuse and contribute to wider processes of change (Brown and Vergragt 2008). Members of project teams may spread the lessons learned in various ways. They might see the demonstration project they created as a model that can be replicated. They might also have the view that the technology, the know-how, and the professional capacity exist to promote a major shift in the relevant socio-technical system. Project team members might carry the ideas and engagement "back" to their respective communities of practice (f. ex. a regional society of professionals in a specific field). Market forces in the industry might also facilitate diffusion. An important achievement of an experiment would be to capture the interest of consumers, businesses and societal institutions. This could lead to further experimentation in the same type of technology and social arrangements, and additional investments (Brown and Vergragt 2008).

Adaptation and accommodation of elements of pioneering projects might be more likely than up-scaling projects the way they were initially done. Maybe only the more appropriate, marketable lessons spread. (An example of this will be seen in relation to the pilot project in Kenya presented in later chapters.) "The inability of the more complete versions of radical sustainability to diffuse from the niche suggests both the limited power of the niche and limited capacity of the incumbent regime to become more sustainable" (Seyfang and Smith 2007, p. 597).

A challenge for replication of radically different ways of providing energy or other goods or services is policy makers' risk aversion, according to (Seyfang and Smith 2007). They suggest that the policy culture is not mature enough to appreciate innovation as an experimental process where learning from failure is an important aspect. Failure is often punished by withdrawal of resources. Seyfang and Smith (2007, p. 597) state that "The challenge is to develop support mechanisms that allow grassroots initiatives to revise and continue in the light of earlier difficulties, and diffuse the lessons learnt. Whilst continued funding of failure can be difficult to justify, it seems unreasonable to cut funding from initiatives willing to adapt activities, overcome earlier problems, and continue experimenting. This is the lifeblood of innovation".

Experiment replication is often thought of as a replication of the tangible elements – for instance installing new power plants, according to Brown and Vergragt (2008). They suggest that innovation in socio-technical designs should be thought of as both a process and a product. When replicating a socio-technical design, one may learn from the design and its features, but also about how it was developed and by whom. Every new activity represents a process of learning and innovation. Herein lies a dilemma that will become visible in the

Indian and Kenyan cases: How can process thinking and creating learning processes be combined with attempts on wider replication and up-scaling?

Experiments lead to a technological niche when the number of experiments increases – when more actors are attracted and they start forming networks, sharing ideas, expectations and lessons. According to Raven (2005), experiments should be done in ways that contribute to such processes, which he calls processes of cosmopolitanism. Projects are often not designed with an emphasis on disseminating knowledge, and the learning remains local – i.e. with the companies and other involved actors. Raven emphasizes the need for monitoring results from experiments and for sharing experiences widely, including doing explicit comparisons with similar experiments in other locations, publishing results, and organizing seminars and meetings. Furthermore, Seyfang and Smith (2007) suggest that local action must connect with higher-level policies, capabilities and infrastructures, and that grassroots innovations should take advantage of windows of opportunity that may emerge.

Although a large number of practical projects are necessary on the way towards socio-technical systems change, they are not sufficient. Institutionalization has to come in addition, and is politically and economically difficult (Smith and Stirling 2010).[9] Socio-technical experimentation in combination with various governance efforts paves the way for institutionalization, which in turn facilitates further strengthening and spread of the activities on the ground. Institutionalization "involves mobilizing serious selection pressures against the incumbent regime and redirecting vast institutional, economic, and political commitments into promising niches along desired pathways" (Smith and Stirling 2010, p. 7). Institutionalization is a necessary part of up-scaling, through "increasing the scale, scope and intensity of niche experiments by building a constituency behind a new (sustainable) technology. This sets in motion interactive learning processes and institutional coordination and adaptation, which helps to create the necessary conditions for the successful diffusion and development of those technologies" (Coenen et al. 2010). According to Fuenfschilling and Truffer (2014), institutionalization can be viewed as the process of structuration – i.e. the gradual making of the structures or elements that make up socio-technical systems and strengthening their position in society. They point out that an important part of such processes is the creation of new meaning systems, "emerging institutional logics" and societal discourses. The actors who carry out socio-technical experiments often attempt to contribute to such "institutional work" (Fuenfschilling and Truffer 2014).

2.4. Spatial transfer of socio-technical innovations

While studying local initiatives for social and technological change, this dissertation also studies a strategic effort for transferring social and technological (i.e. socio-technical) innovations between them. Two main fields of literature are relevant for such spatial transfer of innovations: The literature on "inter-local learning" and some of the literature on technology transfer to countries in the South. These are presented below.

---

[9] Institutionalization is not defined in the publication referred to, but is here taken to mean the gradual making of institutions, which have been defined as "sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups and organizations" (Edquist 2005, p.188).

2.4.1. "Inter-local learning" – technology transfer as learning between projects

The concept of "inter-local" learning is used about learning between projects, both within and between countries, by researchers working from a socio-technical systems perspective. According to Raven et al. (2008), inter-local learning means learning between specific projects in different geographical contexts, where a follow-up project copies successful elements of a previous project. This is one of the sources of knowledge for project implementers.

In addition to such direct learning between projects, insights accumulate and translate from local experiments into a generic field of context-independent lessons that new projects draw on. Such lessons can be seen as emerging structures or rules of a socio-technical system – an aggregate niche level, also called the "global" niche level, but not global in the geographical sense (Raven et al. 2008, Schot and Geels 2008). This is described as an "emerging field or proto-regime supported by a network of actors concerned with defining de-contextualized, shared rules such as problem agendas, search heuristics and abstract theories and models independent of their local context." This is another way of describing how a niche comes into being and gradually develops. These niche socio-technical systems ("reservoirs of rules") influence new activities on the ground in other places.

The new socio-technical experiments thereby draw on experiences from other past and similar projects, and represent local variations of a generic design (Coenen et al. 2010), in other words a contextualization of a niche innovation (Raven et al. 2008). Examples of structures or rules that influence new projects are general organizational models, financing structures, technical standards and shared ideas about what users want (Raven et al. 2008). Experiences from the local project level is shared and aggregated through different types of mechanisms, including "aggregation activities" by dedicated formal and informal actors. These activities include standardization, model building, handbook writing, online forums, site visits, and excursions.

Conversely, when actors draw on generic lessons in new projects, it is pointed out as important to focus on local "re-invention", because projects should be "locally embedded; provide local benefits; establish continuity with existing physical, social and cognitive structures; and apply locally appropriate communication and participation procedures" (Raven et al. 2008, p. 469). Local benefits may include local energy independence or creation of a new marketable product, local employment, exchange of resources between town and country, improvement of community services, and continuity with existing physical, social and cognitive structures and resources (Raven et al. 2008, Späth and Rohracher 2012). This is relevant for direct learning between projects, which is important in this dissertation. Moreover, the aggregated niche experience is also likely to have an impact during learning between specific projects.

Although inter-local learning has been considered important for socio-technical innovation, there has been little elaboration on *how* it could be carried out and utilized in strategic and effective ways, as is investigated in this dissertation. Through analyzing a stepwise activity for transfer of social and technological innovations between India and

Kenya, the dissertation contributes to filling this gap. Interestingly, several of the concepts on socio-technical change presented earlier in this chapter might be helpful for exploring how to utilize the opportunity for learning and inspiration between innovative uses of technology in different places and countries. These are concepts that enhance the understanding of technological change as socio-technical, and thereby how examples to learn from can be understood as part of wider socio-technical systems (niches and regimes), and societal contexts (geographical levels, socio-cultural contexts).

Sensitivity to local context and the local embeddedness of the projects seem to be key aspects for success of such transfer of innovations. Since an emerging socio-technical system is the result of co-evolution of technical and social elements, new projects contribute to the continuation of such a co-evolution process in new places, regions and countries. Local, socio-technical innovation shapes local contexts, and local contexts shape local socio-technical innovations (Coenen et al. 2012, Späth and Rohracher 2012).

Figure 2 below has been used in the literature in order to show learning processes between the local and "global" niche levels, and between local projects (Geels and Raven 2006, Coenen et al. 2010, 297). The mechanisms shown in the figure represent processes of building up socio-technical systems in niches, of which inter-local learning is only a small part. This dissertation zooms in on the potential for systematic knowledge sharing and learning between specific projects in different places and countries (marked by bold arrows in the figure), and explores it through action research. The process of transferring socio-technical innovations from India in order to develop a project in Kenya can be seen as a case of inter-local learning, and simultaneously as international knowledge sharing or spatial transfer of socio-technical innovations in general.

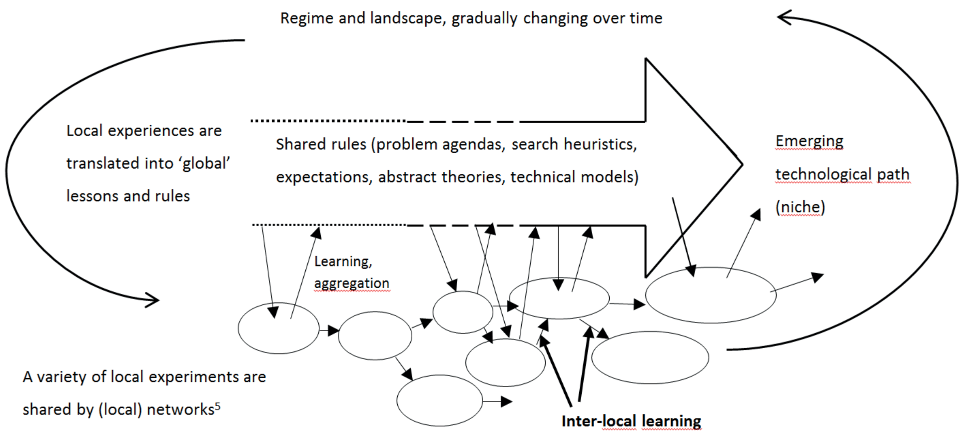

Figure 2. Inter-local learning and aggregation of lessons learned, based on Coenen et al. (2010) and Geels and Raven (2006)

There is a call for a more reflexive understanding of the conditions under which findings from one spatial "transition" context may be transferred to another one (STRN 2010). When analyzing the "territorial setting" and the socio-spatial construction of socio-technical change, it becomes possible to understand how and why geography matters, and how much influence the local actors have had on the local changes (Coenen et al. 2012).

2.4.2. Literature on technology transfer to countries in the South

A large part of the literature on international technology transfer to countries in the South has focused on how developing countries can catch up with rich industrialized countries in technological advancement, industrial production and production of their own capital goods, as well as large-scale energy and water supply (Maskus 2004). Channels for technology transfer between countries identified in this literature include trade in products, trade in knowledge, direct foreign investment, and international movements of people, and the transfer has traditionally been assumed to go from North to South. Central issues discussed are the policies of technology exporting countries, spillover effects from foreign direct investment, protection of infant industries and competition issues. Authors have also focused on norms and standards set by multilateral organizations, trade terms and intellectual property rights (Soete 1985, Reddy and Zhao 1990, Grübler and Nakićenović 1991, Bell and Albu 1999, Hoekman et al. 2004). Such literature on technology transfer does not provide insights on transfer of knowledge, experience and equipment relevant for implementation and use of technology in local communities, which is the focus of this dissertation.

Some other literature on technology transfer has been produced in relation to transfer of "clean technologies" to combat climate change and at the same time create economic and social development in the South. One part of this literature concerns so called "leap-frogging"; focusing on how developing countries could bypass the "old fashioned traditional technologies" (Mielnik and Goldemberg 2002). Like the literature on "catching up" the literature on "leapfrogging" is less relevant for this dissertation since it is mostly focused on the macro level of foreign direct investment, energy intensity in the industry and pollution trends. A critical voice in the literature on leapfrogging is Perkins (2003, p.185) who states that national governments in developing countries would have to "challenge entrenched domestic and foreign interests" to make leapfrogging possible, because the preferences of such interests lie to a greater or lesser extent along a business-as-usual path.

Some of the literature on transfer of "clean technologies" has started to have an integrated view on the social and the technical, and see socio-technical change as social learning processes (Martinot et al. 1997, Halsnæs et al. 2007). A special report from IPCC on technology transfer (Metz et al. 2000) was worked out as a collective effort of around 200 authors from across the world representing a variety of disciplines.[10] The report presents a view that technology transfer constitutes a broad set of processes covering the flows of know-how, experience and equipment. It comprises of the process of learning to utilize and replicate the technology, including the capacity to adapt it to local conditions and integrate it

[10] Reference is given to the report itself instead of the underlying academic literature, because the report goes beyond previous literature in its descriptions of what technology transfer may be constituted by.

with indigenous technologies. Elements of successful transfer include consumer and business awareness, access to information, availability of a wide range of technical, business, management and regulatory skills, and sound economic policy and regulatory frameworks. Participatory approaches and strengthening of networks are suggested elements, and it is recommended not to ignore late stages of the transfer process. The report emphasizes the sustainable development perspective of technology transfer, i.e. the importance of creating social and economic development at the same time as addressing climate change and other environmental problems, which is also pointed out by Román et al. (2012).

Barriers to technology transfer mentioned in this literature are especially related to the human and institutional capacity as well as science and educational infrastructure in the countries where technology is going to be used, called "recipient" or "host countries". A lack of ability to develop innovations and replicate them is also mentioned. So-called "active technological behavior" by technology importing firms is called for to avoid technological dependence and stagnation. Emphasis is put on the characteristics of the "recipient", including ability to absorb and use new technology efficiently (Metz et al. 2000, Halsnæs et al. 2007, p.160).

Some of this literature has come as a reaction to the way technology transfer is seen in practice within international mechanisms for technology transfer, such as the Clean Development Mechanism (CDM). It is argued by Byrne et al. (2011) that the current form of CDM seems to be influenced by an understanding of technology as "hardware", with some understanding of the need for "software", mainly in terms of cooperation and maintenance skills. A range of societal problems are assumed to get solved through such mechanisms for transfer of low-carbon technologies, including problems of energy access, equity, security, and environment. However, considerations of social conditions and economic realities of the people who could benefit from the technological change are often insufficient (Murphy 2001).

Spatial transfer of technology, including South-South transfer is also mentioned in literature on technological, economic and social development in the South, in relation to areas like telecommunication and use of renewable energy technologies, which are enabling technologies that contribute to social and economic development, even though they are outside of the traditional manufacturing domain (Romijn and Caniëls 2011). These authors argue that the persistent poverty problem might require more emphasis on the development of innovative social and technological changes based on knowledge present in developing countries, suitable for local needs and informed by local institutional and socio-economic contexts. They find that some innovation activities require the capacity for prototype development and capabilities to initiate manufacturing, which only a few large developing countries will be able to do in the foreseeable future. Since innovations from these countries are likely to be suitable for poorer developing countries, South-South technology transfer and cooperation has a large potential according to (Romijn and Caniëls 2011). Moreover, they argue that creative, adaptive innovation should be encouraged, including technology blending and grassroots-driven indigenous innovations. The need for increased attention to creative innovation capabilities in efforts for technological change is also highlighted by Byrne et al.

(2011) who posit that local socio-technical experimentation is an important part of technology transfer for cultivating relevant knowledge.

All parts of this dissertation are based on a socio-technical systems approach, although the perspective has mostly been developed and used in the context of rich, industrialized countries in the North. Researchers from specific countries dominate the Dutch-originated literature on sustainability transitions (Coenen et al. 2012). Although some studies have been carried out in areas of the South, these are still exceptions, including Berkhout et al. (2010) in Asian countries, Byrne (2009) in Kenya, Ahlborg (2015) in Tanzania and Mozambique, Romijn et al. (2010) in India, and Ulsrud et al. (2011) in India. These studies show that these theoretical tools can give fruitful insights in factors influencing the emergence of innovative socio-technical systems in a diversity of geographical contexts. However, it remains important to question and reconsider the relevance of these theories in contexts different from where they originated, as suggested by Coenen et al. (2012). They call for an increased territorial sensitivity in this field of research, with more reflection on the spatial contexts and conditions, and more attention to the geographical diversity. The conclusion of this dissertation, Chapter 9, provides a reflection on these issues.

2.5. Chapter conclusion

This chapter has shown that a broad socio-technical systems approach provides important insights for investigating this dissertation's two interrelated research themes and their two corresponding levels of research: the research on socio-technical designs and actual workings of the solar power supply cases in India and Kenya, and the process of transferring socio-technical innovations from India to Kenya. These analyzes are intertwined and mutually supporting, as the following chapters will demonstrate.

An interesting theoretical question has been identified above concerning how socio-technical experimentation can be designed or organized in order to enhance learning and innovation. The cases analyzed here have the potential to show factors that might play a role. This question will therefore be included as a third question for discussion in addition to the two main research questions presented in Chapter 1. Another interesting theoretical topic that can be extracted from this literature review is the interaction between socio-technical experimentation and spatial transfer of innovations. Transfer of knowledge and experience from other places and countries may contribute to fruitful experiments, and socio-technical experimentation can contribute to, and is a necessary part of such spatial transfer processes. In addition, the analysis gives an opportunity to reflect upon the role of social science contributions, including trans-disciplinary research and constructive research (including action research), for the transfer of innovations and socio-technical experimentation. Conversely, the analysis provides an example of how engagement in practice by the researcher might possibly give additional or different academic insights. These theoretical and methodological interactions are outlined in Figure 3 below, and reflected upon in Chapter 9 on conclusions.

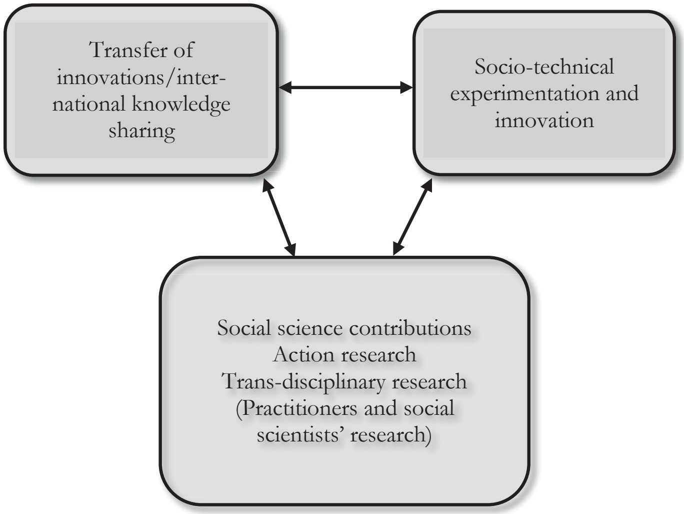

Figure 3. Mutual interactions between different theoretical and methodological approaches to social and technological change applied in this dissertation.

The empirical analysis is conducted in an explorative way by bringing in theoretical concepts where they are deemed relevant. The theoretical approaches discussed above represent important aspects to take into account when studying local energy systems and how they are transferred to new places. However, the theoretical concepts are rather general, and need to be "translated" to a more specific framework of analysis adapted to the cases. The next chapter combines the theoretical insights explained above with literature on off-grid power supply as inputs into a less abstract framework for the village case studies. The framework at the same time structures the description of the transfer process from India to Kenya. All of the four empirical chapters (Chapter 5 to Chapter 8) serve a double purpose because they contribute to both levels of research. The case studies on the solar systems feed back on the understanding of the transfer process because they show what the actors attempt to transfer, what becomes transformed in the process and how, and which kinds of outcomes emerge and why.

Chapter 3: A framework of analysis for the study of local electricity systems

This chapter presents a framework of analysis for case studies on village-level infrastructures, and thereby develops the details of how to analyze the cases in India and Kenya. The framework is supposed to shed light on conditions that make new socio-technical configurations on village-level power supply useful, viable and replicable. The framework is informed by the theoretical insights presented in the previous chapter as well as empirical literature on community or village-level electricity systems included below.

The framework of analysis is probably relevant also for studies of other kinds of local infrastructure systems than those studied here. It is suitable for research cooperation between social scientists and technology practitioners, who can complement each other in understanding the different aspects and dynamic interactions in the local socio-technical systems. This dissertation applies the framework in analyzing both the existing village-level systems in India, and the gradual planning, implementation and operation of a system in Kenya. The framework also points to factors that may be important to consider when developing new systems, as was done during the action research in Kenya.

3.1. Main differences from other approaches to village-level power supply

Before presenting the framework of analysis below, a brief explanation of how the framework relates to other analytical approaches used in studies on village-level electricity systems is here provided. As mentioned in Chapter 1, social science contributions on village-level power supply are relatively scarce, and more are needed (Bhattacharyya 2012, Sovacool 2014). Many previous studies of such energy systems concentrate on technical and economic analysis, assessments of alternative technological options and optimization of integrated energy systems (Ramakumar et al. 1995, Iniyan and Jagadeesan 1997, Moharil and Kulkarni 2009, Bhattacharyya 2012). In this study the social and human dimensions are put at center stage, without losing sight of the systems and the technical and economic aspects.

Some of the literature is oriented towards practical advice and policy development. It provides case studies and suggests "best practices" and step-by-step approaches to project implementation and decision making. They also suggest methods for the evaluation of project experience (Bhattacharyya 2012). Some of this literature is written by international NGOs or multilateral organizations dealing with renewable energy issues (World Bank 2008, Bellanca et al. 2013). Such studies point to various elements important for sustainable (or viable) off-grid electricity provision. Although practically oriented, they provide ideas for what kinds of aspects should be looked at in academic, social science analysis of different models for off-grid electricity systems (Cabraal et al. 1996, CEEP 2001, ESMAP 2001, ESCAP 2005, World Bank 2008).

Some social science research investigates the socio-economic impacts of electricity access, and thus focuses on measuring the usefulness of these kinds of power supply for people in poor, remote communities (Chakrabarti and Chakrabarti 2002, Chaurey and Mohanty 2007, World Bank 2008). While this theme is beyond the scope of this dissertation, much research shows the benefits of getting access to basic electricity services. These include various kinds of solar power supply, and the positive impacts on women's situation (Chaurey et al. 2004, Jacobson 2004, Chaurey and Mohanty 2007, Standal 2008, Winther 2008, Kirubi 2009). This dissertation focuses on *how* access to basic electricity services can be possible, as further explained below.

Other studies evaluate systems' sustainability, for example technical, economic, institutional, social and environmental sustainability (Ilskog and Kjellström 2008, Kirubi 2009). The different "sustainabilities" are defined as follows (Ilskog and Kjellström 2008, p. 2675): *Technical* sustainability is about maintaining the energy service during the economic lifetime of the initial investment; *economic* sustainability concerns survival of the service beyond the economic lifetime of the initial investment; *social/ethical* sustainability concerns equitable distribution of the benefits offered by electrification; *environmental* sustainability concerns the conservation of natural resources, avoiding degradation of the environment, and preventing in-door air pollution (which harms people's health); and *institutional* sustainability concerns survival of an organization and its ability to maintain adequate performance with respect to the other dimensions of sustainability. Analysis of sustainability is sometimes conducted through the use of indicators in order to measure performance. Sets of sustainability indicators represent attempts to develop standardized frameworks that can facilitate comparison of a range of (very) different energy systems, from solar home systems to conventional extension of national electricity grids (Ilskog 2008). This dissertation focuses on aspects that are similar to social, economic and other forms of sustainability, but does it in different ways. The analysis emphasizes qualitative, in-depth understandings of how the systems work and for whom, and what can be learned from this on how viable, replicable and socially just systems can be achieved.

The field of resource management and political ecology has developed theories on collective action (Ostrom 2004), which have also been applied to analysis of village-level energy systems (Kirubi 2009). Such theories focus on why some communities fail and others succeed in operating their own infrastructure or natural resources. They consider the capacity and ability of communities to implement, regulate and manage resource use, including local energy resources and power provision. The literature on collective action puts significant weight on internal aspects of a community. Much of the responsibility for success or failure is placed on the local people and their behaviour, their abilities to form social networks, trust each other and cooperate. However, linkages to external actors and resources and characteristics of technology are also included in such analysis. This dissertation finds a socio-technical systems perspective to give a more comprehensive picture of aspects that influence village-level power provision.

Some scholars have started to apply socio-technical systems perspectives on village-level energy projects in the South (Romijn et al. 2010, Ahlborg 2015). These build on some of the same literature on socio-technical change as presented in the previous chapter. They thereby have similarities with this research, although the specific analytical frameworks used and the aspects emphasized are different. Compared with earlier analysis of village-level electricity systems this dissertation places a stronger focus on the entire process of planning, implementing, sustaining, expanding and replicating or building on elements of the systems. This approach also facilitates a focus on the dynamic learning processes of the involved actors, and gradual changes over time.

One aspect highlighted here, but seldom addressed in the literature, is the relationship and cooperation between local actors and project implementers. Specifics include actors' mutual learning and innovation, and project implementers' responsibility to follow-up and assist the community led infrastructure systems in the long run. Moreover, this research found no studies in the literature where action research was used in order to study the development of socio-technical designs and the actual functioning and electricity access over time. The action research contributes to focusing on the specific challenges and dilemmas faced by the different actors involved over time. The research thereby emphasizes the human aspects of social transformation and how these can be better taken into account in energy projects and studies. Importantly, it gives attention to the role of the specific, societal and geographic contexts both at the local level and at higher geographical levels for the design and workability of the local systems and how they fit with people's needs. Such a focus is important not only for the study of energy systems but also for understanding how knowledge and experience of such systems can be transferred spatially.

3.2. A six-step framework of analysis

The following sections describe the framework of analysis and how insights from the socio-technical systems perspective are represented in details of the framework. The studied dimensions are grouped into six main categories, forming a six-step analytical approach. Each part of the framework includes guiding questions related to the social organization of village-level solar power supply. The six dimensions are shown in the figure below.

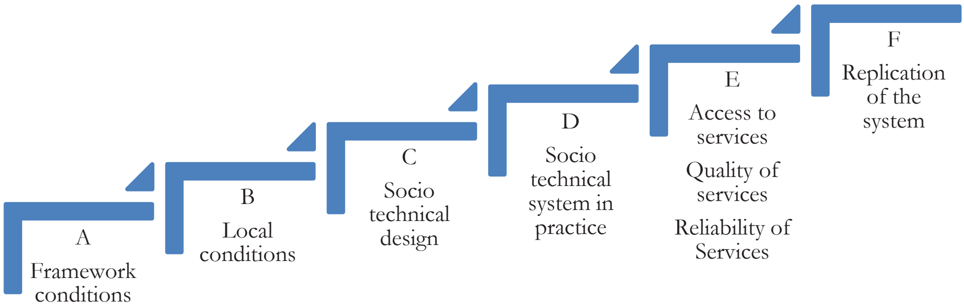

Figure 4. The main dimensions of analysis included in the framework. (Figure originally presented in Ulsrud et al. (2015), made by Debajit Palit).

There are dynamic interactions between the dimensions shown in the figure. The framework is therefore not linear, but can still be seen as different analytical steps. Dimensions D and E are the most important for this analysis, while dimensions A, B and C help understanding them. Dimensions A-E contribute to understanding dimension F. The six dimensions are presented in the following sections, which will refer to previous empirical literature where relevant. Previous studies provide some detail on typical challenges for village-level systems as well as opportunities or "success factors", both for systems based on solar PV technology and systems based on other renewable energy technologies.

3.2.1. Dimension A: The national and international framework conditions and other external factors

Dimension A of the framework concerns how the village-level electricity systems are influenced by factors that are external to the specific, local systems. These factors include national and international framework conditions such as existing suppliers of technical equipment, existing ways of viewing the technology among policy makers and citizens, regulations in the energy sector, and existing expertise on installation and repair. Factors at the national level are connected with international technology and market trends and actors operating at an international level as explained in Chapter 2. Research on dimension A is based on the following questions: What is the role of the national and international framework conditions and other external factors to the local electricity system for the socio-technical design of the system and the way it has been planned, implemented and followed up? How do the framework conditions affect the way a local electricity system works in practice, the kind of electricity access it gives and the way it is, or might be, replicated?

According to theories on socio-technical change, factors and actors outside the local level are likely to influence the local projects. Such factors can be related to emerging technologies like the gradually stronger solar PV sector, or to established electricity regimes.

Broader societal trends not related to electricity supply are also likely to play a role, including historical developments in a region or country.

The quality of available solar PV equipment and the practicalities of purchasing spare parts after implementation are examples of factors related to the national and international solar PV sector that enables use of solar PV technology. Another example is the scale achieved in the national market for solar PV equipment since it influences the cost of importing equipment. As long as it is not possible to import equipment by the container, the cost is often prohibitive, according to practitioners. The existence of companies that devote themselves to this market is therefore very important for affordability of the technology in a specific country. The price level of available technical equipment varies from country to country.[11] Furthermore, government institutions supporting the use of solar PV and other renewable energy technologies may gradually emerge.

Framework conditions shaped by the conventional electricity systems include national government policy and regulations, subsidies for conventional energy systems and lack of political priority of alternatives (IEA 2011, Yadoo and Cruickshank 2012). Preconceived ideas on energy supply among national actors are also likely to play a role. The international and national prices of kerosene (paraffin) and diesel are other examples of factors related to established energy regimes. These influence the economic competitiveness of alternative energy sources. Moreover, conventional technologies like kerosene lamps and diesel generators are familiar to a larger number of people than solar PV technology, and easier available. There might also be strong economic interests that promote continued use of oil products.

Ideology of powerful actors as well as strong societal discourses are also a part of this dimension. For instance, some of the literature (and much of the policy discourse) on off-grid power supply emphasizes decentralization and promotion of a market-oriented approach with strong private sector involvement and community driven development (Jacobson 2004, IFC 2012). Private sector investment and profitable business models for decentralized, off-grid renewable electricity supply are seen as necessary for large scale implementation and provision of electricity to all. The key argument is that since achieving universal access to modern energy services will require significantly larger investments than what is possible through other funding sources, governments should be a facilitator for increased private sector investment. In addition, there has been a tendency of glorifying private, individual solutions (like solar home systems) as well as community level solutions as an alternative to government funded public services to the population (Jacobson 2004). However, based on the last decades' experiences, it has also been suggested that private and public sectors as well as civil society should complement each other in the huge task of providing electricity to all (IEA 2011).

Based on studies in Tanzania and Mozambique, Ahlborg and Hammar (2014) suggest that there is need for public investment and further attention to off-grid electricity provision by national utilities (more staff, better coordination and planning capacity). They found this to be important to encourage bottom-up initiatives (by civil society, private sector and the

[11] Solar panels and other equipment for solar systems are often more expensive in African countries than in other parts of the world, including India, according to Indian, Norwegian and Kenyan solar energy experts.

district level of the public sector) to complement top-down implementation, through provision of capital subsidies (i.e. support for investment costs). Also, donors could provide funding that civil society actors can apply for. However, donors pushing for renewable energy projects without addressing or taking into account the high workload and lack of personnel in governments can represent a problem (Ahlborg and Hammar 2014).

The paragraphs above have provided examples of framework conditions of different kinds likely to influence local, socio-technical designs that actors develop, and thereby the long-term viability of the local systems, the kinds of electricity access they give to the people, and the opportunities for replication of the systems (dimensions C-F). The examples also illustrate interactions between established electricity regimes, emerging niche technologies, and broader societal trends. The examples also point to multiple actors attempting to create new structures, or perhaps maintain existing ones. The actors operate at different geographical levels/levels of governance.

Relevant informants and sources of data on various aspects of this dimension include policy documents, policy makers, experts/consultants, businesses, and NGOs engaged in the field. Other actors with knowledge of the national and international framework conditions or other factors outside the local level can also provide information. Finally, the implementing actors and local operators and project owners will also have good insights in how these factors have influenced their local systems and the way they work.

3.2.2. Dimension B: The local context

Dimension B of the framework of analysis concerns the local, socio-cultural and socio-economic context and geographical characteristics of the area of the electricity system. The research on dimension B is based on the following question: What is the role of the local, socio-cultural context for how the electricity system has been designed, implemented and followed up, for how it works in practice, and for the kind of electricity access the system gives and for whom?

The characteristics of the local context where the electricity system is implemented influences (or should influence) the way the socio-technical design of the electricity system is composed, as well as the actual working and the access to electricity services the system gives (dimensions C, D and E). The potential for replication (or diffusion) in similar contexts is also affected by the context sensitivity of the system. Important characteristics of the local context include population density, settlement patterns and socio-economic conditions (Chaurey and Kandpal 2010). The existence or lack of other economic activities than the electricity system, or activities with an economic bearing managed by community based organizations, can play a role for how the system is designed and for how it works in practice (Kirubi et al. 2009). Existing use of similar technologies is also relevant. Other elements are local power structures, inequities in economic opportunities, and local politics.

Theoretically, this part of the framework represents the specific societal/territorial contexts where technology is to be embedded and integrated in people's lives and practices in the local socio-cultural context. The local context likely influences the way in which the technology is used. The technology and the way people use it also likely gradually influences the context through changes in people's daily routines, priorities, economic situation and opportunities (Winther 2008, Winther 2014). These aspects have linkages to livelihoods, vulnerability and resilience and other bottom up perspectives to poverty, environment, sustainability and development (Eriksen et al. 2007, Ulsrud et al. 2008, Eriksen et al. 2011). Such perspectives show the importance of understanding the daily struggles of the people who are the users or potential users of the electricity services and the kinds of hindrances they face for taking advantage of the available electricity services.

A rich description of the geographical area, including political and administrative organization is useful for analyzing village-level energy systems and their replication. Data on socio-economic conditions, literacy, poverty level, people's livelihoods and agriculture may be available for district or county levels and can be combined with a survey, qualitative interviews and meetings with people in the communities. This helps understanding people's main challenges and their vulnerability.

3.2.3. Dimension C: The socio-technical design and implementation strategy

Dimension C is about the details of the social and technical design of the energy system as intended by the implementing actors, and why it was designed this way. The implementation strategy it is also important. Research on this dimension is guided by the following questions: How was the socio-technical design created? What did the project implementers consider as important objectives for the model, and which opportunities and constraints influenced their room for maneuver? Which considerations influenced the model's configuration and the implementation strategy? Who influenced it and how?

This part concentrates on the socio-technical design of the system the way it has been planned and intended to work. As mentioned the in previous chapters, the elements of a local energy system include the energy services provided, the technical components and their combinations, financing, economic design or "business models", the staff and their responsibilities, and the rules for how people can use the electricity services. Other elements of the system are the organizational set-up and ownership of the system, and plans for how to prevent over-use of electricity and overloading of the system. Many of the system elements are more or less invisible and intangible, for example arrangements intended to create trust and openness in economic transactions. A village-level electricity system is a complex socio-technical system even at this small scale, as will be seen in the empirical chapters.

Theoretically, developing the socio-technical design and implementation process represent early phases of a socio-technical experiment. It includes the learning processes for the involved actors in such phases. It is about a planned, experimental design of innovative socio-technical systems at a certain geographical level, here at the village-level. It is also a plan for a "local transition" in a place; from an existing local socio-technical system – a system for kerosene lighting for instance – to one that can potentially replace the old one to a large extent.[12]

[12] This is the kind of "transition" thinking that led to the project name Solar Transitions.

The system design can be influenced by a range of barriers, opportunities, interests and objectives, including those mentioned under dimensions A and B. Strategies for planning and implementation also likely influence the local socio-technical system design. So do also the kinds of actors involved and the negotiations between them, including the role of potential future users in the process. Moreover, the expectations, visions and values of the involved actors, as well as their background experience, influence their considerations, imagination and ability to be innovative.

There are few studies in the field of decentralized electricity provision that analyze actors' considerations underway in the planning process, including the way contextual factors influence project design and different actors' opportunities to have an impact. However, several studies suggest procedures for planning and implementation processes, for instance that external experts should involve local actors, including women, sufficiently well in all steps of the project and combine the knowledge of the local agents with external technical expertise, management capacity and financial resources (Alzola et al. 2009, Bellanca et al. 2013).

Data on these different kinds of system elements and why they were chosen can be collected from project implementers and others who have been involved in or observed the planning and implementation. Actors may be able and willing to provide information on the objectives and considerations that have influenced the system design, and how the national and international framework conditions (A) and the local geographical and socio-economic context (B) influenced their considerations. They can also explain how they experienced the constraints that influenced their room for maneuver in the design process. However, it might be impossible for the involved actors to pass on all the relevant information and tacit knowledge about long and comprehensive planning processes.

3.2.4. Dimension D: The way the system works in practice and its long-term viability

Dimension D is the most important part of the framework and the dissertation because it concerns the actual working (or functioning) of the local energy system, and its long-term viability/sustainability. The following dimension (E) on the resulting energy access is of course also important because it is the end goal for the whole activity, but that part depends strongly on how the system functions over time. Both dimensions (D and E) are addressed in the sub-questions of research question 1 presented in Chapter 1.

The actual functioning of socio-technical innovations always differs from what was planned and anticipated, as explained in Chapter 2. A range of factors interact with the socio-technical design in shaping how it works in practice for the involved people and the way it continues to change in a dynamic process. The research on dimension D is guided by the following questions: Seen from different actors' perspectives, how does the local, socio-technical system function in practice and why? What were the main changes from the planned model and why?

The following aspects of the system's functioning are important to study:

- The mutual influence between people's practices and the functioning of the system
- The interaction between the technical and social elements of the system
- How the daily operation and organizational set-up functions and why, including the interaction between the involved actors
- The economic performance and its reasons
- The role of changing framework conditions for the system's functioning

The actual roles of women and men in the management, operation and use of the services are likely to play a role for several of these five aspects. Other relevant factors are leadership styles in system operations, and the motivation and inspiration of individuals who are responsible for the system's long-term functioning. Such more or less invisible elements of the system may be decisive.

Theoretically, this dimension concerns the learning process after actual implementation of a socio-technical design, and the differences between the initial socio-technical design and the way it came to work in practice. This relates to the unpredictable, only partly steerable, iterative processes between technical and social elements in efforts to create deliberate socio-technical transformation. These are dynamic processes of influence and change between technology, actors and institutions in socio-technical systems, affected by power relations, social structures and agents' strategies. These processes strongly influence how the local energy system comes to work in practice. The functioning of the energy systems corresponds with the way the socio-technical experiments work in practice and how they fulfill the initial objectives and visions that guided the involved actors. Changes after implementation are also important parts of the innovation process, and part of the explanation of how the systems function.

Another relevant theoretical aspect is the development of new practices in relation to the system, for all involved people and organizations. A related theoretical field is the topic of users' innovation and appropriation of technology, showing how users develop ways of using the system and make it "their own" and how this again affects the technology and the system it is part of. The characteristics of emerging, and perhaps surprising practices can significantly influence the practical functioning of the system. If practices develop that seem to affect the system negatively, responsible actors may attempt to alter these practices, which might be difficult to change once they have become established. Emerging practices can give ideas for how the system, or energy model can become better adapted to the users' needs and thereby be strengthened and improved. Concepts like learning through practice, learning by doing and learning by trying for all involved actors are certainly relevant here (Berkhout et al. 2010).

The actual functioning of the system (dimension D) is influenced by the initial socio-technical design (dimension C) and how it was planned and implemented, as well as how it interacts with its social context at the local level (dimension B), and possibly also by factors and actors at other geographical levels and in other places (dimension A).

Relevant points from energy studies in the South concern challenges for achieving well-functioning practical operation and maintenance, economic sustainability, and general viability (or sustainability). Challenges include lack of available spare parts, lack of local expertise to monitor how the systems function, dependence on the expertise of foreign technology providers, and lack of development of local companies and know-how (Alzola et al. 2009, Camblong et al. 2009). A typical difficulty is to cover the costs of operating and maintaining the systems and reach economic sustainability. A mismatch between the users' needs and the users' payment capacity is one of the reasons for this (Shrank 2008, Alzola et al. 2009, Camblong et al. 2009). Lack of incentives for local operators or community based groups to maximize profit and need for enterprise based models has also been mentioned, as well as difficulty in achieving cost recovery and profitability (Shrank 2008). A common problem is lack of focus on long term sustainability among project implementers and a narrow focus on technical installation (Kumar et al. 2009). Lack of involvement of local populations has also been found to be a reason for poor functioning of village-level systems (Alzola et al. 2009, Camblong et al. 2009).

Case studies have pointed to "success factors", meaning features of the energy models that may facilitate well-functioning, useful and viable or sustainable systems. For instance, they suggest that external experts should ensure simplicity in technical installations and maintenance procedures (Alzola et al. 2009, Bellanca et al. 2013). In relation to the challenge of economic sustainability, a situation mentioned as ideal is that supply of electricity might increase people's capacity to generate an income, and thereby also to pay the electricity tariffs needed in order to cover the costs of operation and maintenance at the power plant (Kirubi et al. 2009, Yadoo and Cruickshank 2012). This can be combined with subsidies on connection fees and electricity tariffs, although this creates a financial burden for project implementers (Ahlborg and Sjöstedt 2015). Another suggestion for achieving good economic performance is that the users of the power plant provide direct contributions to the investment, combined with financial tools such as subsidies and loans sufficient to economically support the project in the long term (Alzola et al. 2009). Others do not find this to be important (Yadoo and Cruickshank 2012). The systems should be modular to facilitate expansions, because the electrification process gradually makes more people interested in becoming connected (Alzola et al. 2009).

Interestingly, literature on community energy projects in Europe shows that community energy projects (as well as other community projects) in the North face many similar challenges as community or village-level energy projects in the South. These projects are based on wind, solar, biomass and heat pump technologies, and the cases mentioned in literature are mostly in the UK, Scotland, the Netherlands and Germany. They include cooperatively run small-scale energy projects started or run by different kinds of civil society groups, including voluntary organisations and cooperatives, sometimes in partnership with social enterprises, schools, businesses, faith groups, local governmental or utility companies. Economic self-sustenance is not only a challenge for projects in the South but also for projects in the North. Some projects in the North struggle to survive, lacking time and resources for developing the activity. The projects thereby often fail to develop resilience and robustness to various shocks like funding cuts, key people leaving, turnover of volunteers, burnout of activists and conflicts between involved actors. Another challenge seen in projects in the North as well as in the South is micro-politics that make them inclusive to some and exclusive to others. Finally, some community members' values may count more than others (Seyfang and Smith 2007, Romijn et al. 2010, Hargreaves et al. 2013, Seyfang et al. 2013, Avelino et al. 2014).

Factors that contribute to well-functioning projects (for local grassroots innovation projects in general, including power supply) in European projects include participants having different values from the mainstream. Additionally, key individuals and champions, resources, supportive contextual factors and a particular combination of skills are needed in order to get the projects up and running (Seyfang and Smith 2007, Walker and Devine-Wright 2008, Avelino et al. 2014). Advice and support from experts ("intermediaries") is important in order to initiate community energy projects, and for providing training to participants. Studies in both South and North point out the importance of using local contextualized knowledge on what works in a certain locality and what matters for local people (Seyfang and Smith 2007, Walker and Devine-Wright 2008, Hargreaves et al. 2013, Avelino et al. 2014). European projects, for example, show that "despite every best effort to learn from previous experience in the sector, each project faces some very context-specific challenges which will not necessarily be encountered by others or known about in advance" (Seyfang et al. 2013, p. 21).

The central research task on this dimension D of village-level infrastructures is to study the actual functioning of the power supply system by combining the perspectives of those who operate it, those who are using its services, those who are not using the services, the implementing actors, the local leaders and other observers or participants in the system. People who have developed and implemented pioneering activities for social and technological change often have a very good understanding of why the outcomes are different than expected, and how these experiences led them to adjust the system underway. Their understanding often came the hard way through practical experiencing. Statistics of economic performance can also be important in order to assess the long-term economic viability as well as the features of the electricity access and how people are using the services and when.

3.2.5. Dimension E: The types of electricity access created, for whom, and why

Dimension E considers the types of electricity access that the implemented electricity system actually provides, for whom, why and when, and what the users and non-users of the system think about it and why. It is important to understand why some people exert the efforts and costs for switching from previous uses of energy, and what is hindering others from doing the same. Other themes of the study are which electricity services people prioritize and why, and how and why the use of electricity changes and varies over time (Ahlborg 2015). Dimension D described above has a strong impact on this. The guiding questions include the following: What types of electricity access has actually been created, who is able to and interested in using it and at what times, and what are the factors that influence people's ability to use the electricity services? To what extent has broad access, useful, and affordable services of good quality been achieved?

The goal of the actors' efforts on system design and practical functioning of the system is to provide affordable, useful and reliable access to electricity services for somebody. All the aspects mentioned above influence what kinds of electricity access can be offered and who can be able to benefit from these. A whole village community is normally the target group for the electricity services from a village-level system, and the implementing actors may have specific aims like improving education, health and productive activities.

Both governments and experts within the conventional energy sectors mostly see access to electricity as a dichotomy of either having access to a conventional electricity grid or not (World Bank and IEA 2013), and expansion of such grids has long been regarded as the universal solution for provision of electricity. However, extending the grid to a village does very often not lead to a kind of electricity access that most people need and can afford. Also, conventional electrification is not realistic or possible in many areas, requiring actors to find other solutions (IEA 2011, World Bank and IEA 2013). Moreover, research and practical experience show that it is important to understand energy access as a multi-tiered, multi-faceted group of services and supplies. Electricity (or other energy carriers) are not needed in themselves, but through the services they give, such as lighting, charging of phones, information and communication (Winther 2008, Bellanca et al. 2013).

The UN uses a three-step scale to denote various types of energy access that are provided by different types of energy systems: Level 1 – basic human needs (electricity for light, education, health, communication and community services, and modern fuels for cooking or improved stoves for cooking with biomass[13]), Level 2 – electricity, modern fuels and other energy services to improve productivity (e.g. water pumping for irrigation, mechanized tilling, commercial activities for agricultural processing or cottage industry, and fuel for transport), and Level 3 – Modern society needs (energy for many more domestic appliances, increased requirements for cooling and heating space and water, private transportation – total electricity usage is around 2000 kWh per person per year).[14]

The cases studied here represent attempts to take the first step – the step from no or minimal electricity access to access to several basic uses of electricity (including small business uses). The cases also show the needs for gradually reaching the next steps, when people gradually find new ways in which electricity can benefit them.

The quality of the electricity services might be affected by technology-specific factors such as limited hours of supply and limited quantity of electricity, which are among the weaknesses of off-grid solar PV systems. Affordability for the users of electricity has been pointed out as a central challenge by Alzola et al. (2009) and Camblong et al. (2009). Models that allow for payment for lighting services such as lantern rental can increase affordability and flexibility for the users. People might prefer to pay for the electricity service instead of owning solar lighting systems, since the latter creates a higher financial pressure (Bhattacharyya 2012, Wong 2012, Palit 2013). Rental services help individuals and households avoid paying large lump-sum expenses for deposit or purchase.

[13] Energy for cooking is also an important area, but cooking is a different field of research and practice. Cooking with electricity is not a realistic option, neither technically nor economically, in off-grid electricity systems of the kinds studied here, and is neither seen as an efficient way of using electricity in general (Jain et al. 2015).
[14] http://www.un.org/millenniumgoals/pdf/AGECCsummaryreport[1].pdf

Political factors might also influence the electricity access, for instance if powerful actors influence the system more than others due to existing social hierarchies based on class, gender, age and ethnicity (Winther 2008). An example is the location of grid-lines in a village in terms of whose houses it passes nearby. This and other diverging interests might in turn influence the opportunities for different people to benefit from electricity services, and to further influence the way the local infrastructure works.

Data on dimension E can be obtained through observation and power plant statistics of the user patterns, interviews and surveys with users, non-users, operators and village leaders, as well as users' feedback to local staff members or committee members. The research on this dimension can be expanded beyond the scope of this research to also consider how the electricity services may contribute to social change locally, including impacts on the users' socio-economic situation.

3.2.6. Dimension F: Replication of the local energy system

The last dimension of the framework, dimension F, goes beyond the specific, local case, to replication and diffusion of a pilot or demonstration project. Replication is here taken to mean that project implementers or others build on a model they have tried out or observed, and repeat or further develop elements of it in new activities. Replication is rarely or never a direct copy of a socio-technical configuration, because lessons are learned and additional ideas are brought in underway. As mentioned by Brown and Vergragt (2008) it has to be a learning process every time a socio-technical design is built upon in new activities.

The research on dimension F is guided by the following questions: Which activities for replication, institutionalization and diffusion of learning from the project activity can be observed and why did they occur? What is the potential for replication and institutionalization of the studied socio-technical design, for whom and where? What are the barriers? Based on the practical experience, is it possible to replicate the model or parts of it or scale it up? Is it desirable?

Theoretically, this dimension relates to conditions that might enable social actors to put substantial efforts and resources into increasing the scope of their activities, even though these are still experimental and outside mainstream ways of doing things. Thus, it relates to processes of niche formation and system innovation, including learning from experiments, and accumulation of knowledge and experience on the use of a technology. Niche processes of learning, formation of expectations and networks thereby facilitate replication, and are themselves stimulated by replication or increased numbers of experiments. Replication is also likely to be affected by (and also affect) attempts of institutionalization of the niche system through governance efforts. These can facilitate and encourage the socio-technical experimentation and innovation. This dimension also relates to how the niche space/protective space is shaped and negotiated by involved actors in niches and regimes, and how niche actors work to "empower the niche" in the context of the regime actors and institutions.

Replication, the way it has been described here, is often defined as up-scaling in discussions on off-grid renewable energy. Up-scaling then refers to "rolling out" a project in hundreds or thousands, for example through an institutionalized, standardized government program or through companies who succeed in selling a large number of their goods or services. Some energy experts distinguish between replication and up-scaling. Replication is then repeating or building on the pilot project in relatively low numbers, compared with scaling up. In the transitions language, this kind of up-scaling of off-grid power provision would mean a strengthening of the socio-technical niche, but it would not be a transition to a new electricity regime.

Large scale replication of village-level projects can be difficult. It is suggested by Palit (2013) that implementation of off-grid projects in clusters can assist in the management of the projects. An example is found in Chhattisgarh state in India where Chhattisgarh Renewable Energy development Agency (CREDA) runs a large number (several hundreds) of small solar plants, including small mini-grids. The operation and maintenance is organized according to clusters of 10-15 villages. The clusters are supervised by a mobile technician who gives advice to the operators in each power plant and performs maintenance that the operators cannot do on their own (Millinger et al. 2012).

Parallel challenges can be found in community energy projects in Europe. Projects may be difficult to replicate in a large number because they are designed to be small scale and rooted geographically. Such projects are radically different from mainstream solutions. Therefore it might be difficult to achieve wide diffusion without reformulating and reinterpreting them, through standardization and simplification (Seyfang and Smith 2007, Seyfang et al. 2013).

Data on replication can be obtained by observing attempts of carrying it out, asking about project implementers' experiences and various participants' views on what is replicable, by whom, and which barriers were met. Moreover, policy makers' views on which kinds of energy models should be replicated or "scaled up" might also provide understanding of why some models are replicated and others not, in terms of powerful actors' visions, values, expectations and motivations. Asking project participants what they found to be useful about the project can reveal other kinds of learning outwards from the experiment. This includes what they learned and how they benefitted from this in other activities, including new collaborations, networks and initiatives.

Some of the outcomes from socio-technical experiments, for example learning and inspiration provided for other projects may not be easy to identify because they might appear a long time after the active phase of the experiment or in a place that is far from where the experiment is located. For example, the solar mini-grids in Sunderban Islands in India might not be seen as a full success in terms of leading to wide replication of exactly the same model. However, they have provided learning and inspiration to other projects. The demonstration project in Kenya analyzed in this dissertation is one of the activities that have been inspired by it. The effects in Kenya of the learning and inspiration from these projects in India are located at a large distance from the examples, both geographically, time wise and in terms of differences between the solar power models. These are not easily identifiable for somebody who studies the outcomes of the Sunderbans projects.

3.3. Summing up the framework

The dimensions presented in the sections A-F above describe the variety of factors that may influence the functioning, usefulness and replicability of village-level electricity supply systems or other socio-technical experiments at the village or community level. Such factors also influence the kinds of extended effects the projects may lead to in terms of strengthening emerging socio-technical systems in niches. The case study framework is summarized in Figure 5 below, showing the embeddedness of the local electricity systems in societal contexts at different levels. The dimensions influence each other, as explained above.

Based on the understandings facilitated by this framework, one can give well-founded answers to the research questions posed in this dissertation. The framework is further described and demonstrated through the analyzes of the Indian and Kenyan solar energy cases, which also show how it contributed to the transfer process between them.

A) National and international framework conditions

- Challenges of rural electrification in the county
- Policy and regulatory framework, programs and incentives

B) Socio-cultural and geographical context at the local level

- Livelihoods, socio economic conditions, existing infrastructure, political and administrative organization, existing community projects, local politics.
- Energy needs, current energy use, daily practises.

C) Local electricity system design, social organization and technical solutions used

- The visions that guided it
- Services delivered
- Technical design
- Financing
- Operational and economic design
- Ownership and management design
- Support services for local operators and monitoring
- Reasons for the design and who influenced it

D) Actual functioning of the system, seen from different actors' perspectives

- Differences from how it was intended to work, and their reasons
- The mutual influence between people's practices, and the functioning of the system
- The interaction between the technical and social elements of the system
- How the daily operation and organizational set-up functions and why, including the interaction between the involved actors
- The economic performance and its reasons
- The role of changing framework conditions for the system's functioning
- Learning and innovation processes – changes underway

E) Actual access to electricity services for different groups

- Quality and relevance of the electricity services
- Factors that influence availability, affordability and convenience for the users
- The actual use of the services

F) Replication/diffusion

- Observed replication and learning based on the project
- Differences from the previous project(s)
- Who replicated, who financed
- Drivers and barriers/facilitation
- Potential for further replication

Figure 5. Overview of the framework. There is a dynamic interaction between the different dimensions. The strongest focus of this research is on dimensions D and E.

Chapter 4: Research methods

This dissertation research was carried out as three interrelated parts with different methodological approaches, to achieve different purposes. The purpose of the case study in the Sunderban Islands in India was to gain insights on the social organization of village-level solar power supply. It was both a case study in its own right, and it was conducted in order to facilitate transfer of findings to Kenya. It can be seen as a constructive study, as explained in Chapter 1, because it sought to learn from an existing case about how something can be done. The purpose of the second case study, the action research in Kenya, was to investigate village-level solar power supply through developing a model suitable to Kenyan villages, based on the learning from India and studies of contextual factors in Kenya. This was another kind of constructive study where the knowledge, experiences and methods of social scientists, energy practitioners and people in local communities were combined. The purpose of the overarching documentation and analysis of the whole process constituted by the Indian and Kenyan cases was to better understand how innovations, knowledge and experience can travel from where they were created to a new place in a different part of the world. This overarching analysis focused on the characteristics of the process itself and how learning between the Indian and Kenyan cases took place. This analysis of the transfer process runs as a thread through the analysis of the Indian and Kenyan cases, and is brought center stage in the concluding chapter (Chapter 9).

These three parts formed two, mutually supporting levels of research, as explained in Chapter 1. The first level concerned the substance of the transfer process and related to the theme of how village-level solar power supply can be socially organized (based on the two case studies). The second level concerned the transfer process itself and how it unfolded. The combination of the three research activities at these two interrelated levels contributed to the dissertation's objectives to study emerging potential solutions for access to basic electricity services for people who are not being served by conventional extensions of electricity grids (village-level solar systems), and how such potential solutions can travel and be translated.

4.1. Research approach

A qualitative approach is necessary in order to get a deep, detailed and holistic understanding of social phenomena – how they unfold and why. Qualitative methods make it possible to view a social unit through the eyes of those social actors who are involved or affected. The interaction between actors' efforts to create social change and established structures can best be studied through the experience, knowledge and practices of the involved individuals (Peet

1998, Fangen 2010, Silverman 2011). The perspectives of a diversity of actors are needed. The different parts of this research were therefore based on a qualitative research approach, partly in combination with action research. In addition, some quantitative data were collected as a supplement, in order to shed light on complementary aspects of the studied units (Patton 2002).

By adding action research to a research design, the researcher is no longer only a researcher, but also one of those individuals who deliberately attempt to create new social structures. This gives an opportunity to carry out the research from a central placement in the studied process and makes it possible to be present and participate, physically and mentally, and observe the process from the inside out and bottom up.

Qualitative research as well as action research requires a pragmatic and flexible approach to the research design and research process, in line with a pragmatic stance in social science. Methodological *appropriateness* is then the primary criterion for judging methodological quality, because different methods are appropriate for different research tasks and situations (Patton 2002). A pragmatic and flexible approach has been necessary here for three main reasons. Firstly, qualitative research methods both require and allow for adaptation of the research to changing circumstances underway in the research process. For instance, the researcher might change methods for data collection in order to get access to data that appear to be important underway (Hammersley and Atkinson 2007, Fangen 2010). Secondly, as illustrated by (Haugen 2013), reconsidering and changing the course of the research process underway can be important when following flows and relations in the making, since these are constantly changing. The research has to follow the actors, their relations and actions, and their attempts to shape new social structures. Thirdly, a flexible and pragmatic approach is an inherent part of action research, as will be further explained below.

4.1.1. The field

This research was *multi-sited* as a consequence of the strategy to study examples in one geographical context and transfer insights to another context. A multi-sited research field is composed by different points of observation that are interrelated (Fangen 2010). This research followed a process as it unfolded, and the process included two case studies in two different world regions. The social space of the transfer process was defined by the local cases as well as the interaction and relations developed between actors who collected, carried, shared, created and tried out ideas and knowledge in and between different geographical contexts.

As explained in the chapters on theory and framework of analysis, the relevant social space stretched beyond the local level where the technology was used. The local cases and the learning between them were studied as part of the local, national and international contexts they were influenced by and were part of. The study therefore has similarities with extended case studies, which establish relations between the research at the local level and national contexts, and use the knowledge of the national context to better understand the phenomena studied at the local level. This approach allows for interesting comparisons between countries, which can show differences in the room for maneuver for social actors (Fangen 2010).

Within each country the fieldwork therefore *moved between geographical levels of analysis*, or rather between actors representing different levels of governance, and experts who operated in different parts of the countries and internationally. While the primary geographical level for the research was at the village-level, the relevant actors were also found at other levels – from the villages via district headquarters, regional cities and capital cities, with the village and capital cities as the most important levels.

In addition to multiple sites and levels, *multiple times* for studying the field is fruitful when studying ongoing events (Haugen 2013). The timing of a research activity often receives little attention, but can play a large role for the findings (Patton 2002). For instance; the economic situation and workload of rural people might be very different at the beginning of a dry season than at the end of it, and their time or economic means to utilize options given by electricity access might thereby also vary. In India, fieldwork was conducted once, with some additional data collection after 4-6 months. In Kenya, since the action research took place over five years and the events were documented and studied as they happened, fieldwork was conducted repeatedly. I visited Kenya ten times over five years and stayed for 8 to 22 days each time. Most of the action research was a process of planning, implementation and follow-up going on continuously, mainly from my office in Oslo and the team members' offices in Delhi, Nairobi, Graz and Oslo, but with close cooperation with the involved village in Kenya through visits by me or other team members, phone calls, and letters.

4.1.2. The methods used

The main research methods used in this research were qualitative interviews, participant observation, informal conversations, and collection of emails and project documents from the whole period of the Solar Transitions project. These methods were complemented by quantitative surveys, statistics from local power plant operations, and geographical data collected through a GPS receiver. Participant observation was used throughout the research process because it is an effective strategy for obtaining information on practices common-sense to the research participants or issues that people are reluctant to discuss, and because long-term observation can provide a holistic picture of a societal phenomenon and the roles of the involved actors (Fangen 2010, Haugen 2013). It is important to look at what people do in combination with what they say. As suggested by Hammersley and Atkinson (2007, p. 169); "…interviews and conversations are important aspects of all fieldwork, but they cannot substitute for proper observation and examination of socially organized action".

Much of the observation at the local level in Kenya was related to the work on the pilot project. It therefore differs from normal participant observation. According to Fangen (2010) an overall aim of participant observation is to be able to describe what people say and do in situations or contexts that are not structured by the researcher. This does not fully apply with regard to action research, where the researcher may have played an important role in shaping the phenomenon people relate to during the participant observation. However, he or she may not directly structure the situation observed, since people's new practices in relation to the social changes influenced by action research may have become part of everyday life for them. This depends on the timing of the fieldwork in relation to the action research done, and the kinds of situations studied, as will be shown.

4.1.3. Action research

The action research literature consists of a variety of traditions developed around the world. One example is the participatory action research on community development in India and several African countries where detailed practical methods and tools have been developed for participatory processes and co-generation of knowledge between researchers and members of poor communities (Herr and Anderson 2005, Chambers 2008, Swantz 2008, Chambers 2012, Mapfumo et al. 2013). Another example of action research traditions is the work on labor conditions and organizational development in various countries, including Norway and the United States. The researcher intervenes in an existing organization with the aim to initiate change processes together with employees or members and leaders, based on social science insights. In Norway such action research has aimed to improve the cooperation between leaders and employees internally in companies, and the research has been important for the development of the laws on working conditions for employees (Engelstad et al. 1970, Kalleberg 1992, Olsen and Lindøe 2004, Herr and Anderson 2005, Sæther 2010).

The most typical feature of action research is that it includes practical intervention by the researcher in a social unit (Reason and Bradbury 2008). The objective of the intervention is twofold – to contribute to processes of social change by addressing questions and issues significant for the participants, and to provide academic and practical knowledge. The action research literature places emphasis on so-called co-generation of knowledge between social scientists and other participants, sometimes also called co-learning or co-design. This means that the academic as well as the more practical knowledge is developed in close interaction between the researcher(s) and other social actors. The non-academic participants are seen as co-researchers (Sæther 2007). For some, action research is primarily a form of practice in the world, while for others it belongs in the scholarly traditions of knowledge generation (Reason and Bradbury 2008). Some social scientists argue that there are types of knowledge that can be better achieved from an action researcher's perspective – where the researchers and practitioners engage one another in a joint research process – than from a position more distant from the studied activity (Engelstad et al. 2005, Herr and Anderson 2005, Sæther 2007, Karlsen and Larrea 2014). Moreover, action research makes it possible to challenge research by confronting it with real life issues.

Despite the claim of action research to be a scientific research methodology, the world-changing objective often seems to be emphasized more than the objective of scientific knowledge production. The Handbook of Action Research states that the primary purpose of action research is "to liberate the human body, mind and spirit in the search for a better, freer world" (Reason and Bradbury 2008, p. 5). Such emphasis on the practical intervention and a tendency to ignore academic analysis and publication has led to a critique of action research for not following academic norms for good scientific work, and for being professional work by social scientists rather than scientific research. The work has been criticized for not fulfilling research requirements of applying theory, posing precise research questions, collecting data, analyzing them and publishing the results in peer reviewed publications (Kalleberg 1992, Herr and Anderson 2005).

Action research has also been criticized for applying its own criteria for validity and research quality. In such instances, the research results are seen as valid if they actually lead to positive social change (Herr and Anderson 2005, p. 55). According to such quality criteria, the outcomes of the action research in Kenya (described in later chapters) could have been used as criteria for establishing validity of the findings. This is not done here. The outcomes are not seen as evidence of how solar power supply can be organized, nor as proof of how a strategy for South-South transfer may work out. A common critique of action research is also that it analyzes practical action initiated by the researcher, who thereby is an insider or practitioner to the studied change process or organization. The research presented in this dissertation has been carried out in awareness of such criticisms.

This dissertation's action research was based on a combination of social science research, planning and practical activities. The two main practical activities were:

1) To develop a local electricity supply project with team members and a village community in Kenya over several years in order to produce academic and practical knowledge on how such electricity supply can be organized and how socio-technical experimentation can take place. (Related to research question one.)
2) To devise and test a strategy for spatial transfer of innovations, international knowledge sharing and common learning in order to produce academic and practical knowledge on transfer of innovations. (Related to research question two.)

This chapter concentrates on the details of the academic research, including the role that the action research played in it. The further details of the practical interventions through action research in Kenya form part of the empirical results presented in later chapters.[15]

Action research has been described as a messy process (Herr and Anderson 2005). In such projects, the research objectives are often defined underway, during interaction with the research participants for instance in a workplace or a community (Greenwood and Levin 1998, Herr and Anderson 2005). In this dissertation, the entire research strategy was planned beforehand, including research aims, overarching research questions, methods for data collection and division of labor among team members. At the same time, the plan was to have an open and explorative process with a local community in Kenya through action research on developing an energy model that could fit there.

The objective of academic knowledge production has primacy in this dissertation. However, in the practical work to create and ensure the functioning of the project in Kenya, research interests were not put before the needs of the real life project. The efforts put into the practical part of the action research were at the same time important for the academic

[15] This research may be perceived as applied research because the social science research is partly feeding into practical efforts for social change. However, this is basic research, which uses practical intervention as part of the research strategy. There is no employer or principal for this research, and there is no element of contract research. The research is initiated by the author, based on the knowledge aims presented. The team of social scientists and practitioners has created a common activity which has been found worthy of the necessary research grant by the Research Council of Norway.

knowledge to be achieved. This was because the practical activities shaped the kind of case that became available for research. Moreover, the academic research supported practice by providing knowledge about the problems to be solved and contextual factors, and by monitoring social practices over time.

The data collection and presentation of results followed similar norms and quality criteria as other social science research. This was in line with recommendations for constructive research as presented by (Kalleberg 1992, 1993, 2009), as explained in the introduction. It was also in line with discussions presented by (Levin and Ravn 2007) on how a researcher can perform academic research of high quality in relation to different forms of involvement in the field, aimed at solving pertinent and practical problems. They prefer the notion of engaged research, which is a slightly wider notion than action research (See Levin and Ravn 2007, p. 6).

Qualitative research and action research have similarities in the possibilities they provide for deep understanding. Based on the literature on qualitative inquiry (Patton 2002, Hammersley and Atkinson 2007, Fangen 2010, Thagaard 2010, Silverman 2011), several similarities with action research can be identified. One similarity is that the researcher aims for deep insights on the social unit studied, to answer how and why-questions about social actors and what they do. As suggested by experienced sociologists in Engelstad et al. (2005): in order to achieve close contact with reality, ensure the societal relevance of the research and to be able to ask good academic questions, social scientists should keep close contact with society and not isolate themselves in specialized research environments. The investigation of themes of which the researcher has some real life experience is seen as an opportunity to achieve a good understanding.

Another similarity between qualitative research and action research is the personal, face to face interaction with the people studied, deep conversations on the research themes, and participation in various activities together with those who are studied (Patton 2002, Hammersley and Atkinson 2007, Fangen 2010, Thagaard 2010, Silverman 2011). It is also common in social science, including qualitative inquiry, to have underlying social and political reasons for seeking knowledge. The social scientist often takes side with disadvantaged groups or points out unfairness in society, or investigates reasons for people's actions in light of how their living conditions have been influenced by social class and other structural conditions (Hubbard et al. 2002, Fangen 2010). However, in action research, the role of the researcher becomes more active. In some action research the researcher has chosen to challenge the people studied (Engelstad et al. 1970, Kalleberg 2009). Another kind of role to take is to be an inspirator, facilitator and catalyst for common work, as was aimed for here. The next sections of the chapter will show how the methodological challenges of the involved position were taken into account in this dissertation in order to achieve balanced data and interpretations.

4.1.4. Positionality and research quality

The research was carried out in awareness that a researcher's position in relation to the phenomena and people he or she is studying has two kinds of impacts. Firstly, the researcher's background and position in society may influence the studied phenomena and people, and thereby the data and research findings. Situations are affected by the researcher's presence, and events occur that would not have occurred if the researcher was not there. Differences and similarities between the researcher and the research participants/informants[16] are likely to play a role for communication and understanding created in the meeting between researcher and informant (Fangen 2010). Secondly, the researcher's situated position in social reality, including his or her ideals, attitudes, background experience and skills as a researcher influences what he or she is able to see and comprehend (Hammersley and Atkinson 2007, Fangen 2010). The researcher's sympathies, personal relations and engagement in social problems may also cause him or her to overlook some people's perspectives or some kinds of explanations, or perhaps capture something that others might not see. The first kind of impact can be controlled by the researcher to a larger extent than the latter (Fangen 2010).

The roles taken in the field by researchers in qualitative research in general, and action-oriented research in particular, have similarities. Qualitative researchers go where the action of the informants are, and may involve themselves in these actions and get their hands dirty through participant observation. They often get to know informants on a personal level and become personally engaged so as to use all their senses and capacities. Both affect and cognition are part of the field experience that contributes to the understanding achieved. argue that "qualitative methodologists question the necessity and utility of distance and detachment, asserting that without empathy and sympathetic introspection derived from personal encounters, the observer cannot fully understand human behavior". The involvement goes a step further in action research, because of activity to create deliberate social change together with others. Since action research has the potential to contribute to social transformation in a more direct way than other research, the choices made underway are political and have power dimensions that the researcher must work through and publicly articulate (Herr and Anderson 2005).

Since the roles of researchers who do action research often change underway in the research process (Sæther 2010), the impact of the researcher on the findings may vary over time and will also vary depending on methods used for data collection. This will influence the quality of data in different ways. In this research, my role as a researcher and action researcher varied and changed significantly underway. During the most intense action research in Kenya I played a leading role in creating an energy system in a village, experiencing the challenges and dilemmas of energy practitioners. After the start-up of the power supply my role became more of an observer, but it still involved responsibility and concern for the functioning of the electricity provision and active participation in practice. My role in the overall transfer process was to be a leader and facilitator, responsible for its progress. The roles taken in this research are explained and reflected upon under the three parts of the research presented below as well as during the analysis.

A risk is that the action researchers' ownership to some of the studied phenomena might make him or her less critical or to overlook issues that an outsider might be able to notice. This potential risk is addressed in the following ways in this dissertation. Firstly, the

[16] I use the concept informants when mentioning respondents to research interviews and surveys to distinguish them from research participants in the action research.

involved position is openly and transparently brought forward, and detailed descriptions are provided on the research process as well as empirical results and interpretations. Secondly, a critical attitude to the results of the practical activity is strived for during the analysis. Thirdly, I put little weight on evaluation of the local energy systems (both the Indian and the Kenyan). The emphasis is rather on understanding how they work in practice and why, and for whom, and what this can tell about factors that have importance for the social organization of village-level models. When analyzing the systems' functioning and the qualities of the electricity access they give, emphasis is put on describing situations and discussing reasons, not on determining success or failure. Further to the same point, evaluation is also not pursued on the overall transfer process. The aim is to understand the way in which it took place, how the outcomes emerged, and what can be learned from it. Fourthly, other team members' views as well as comments from observers have opened up opportunities to assess additional and alternative explanations. Team members represent other perspectives than mine because they have played different roles. They also have different backgrounds and kinds of expertise. Furthermore, they have different relations to the Solar Transitions project than me. For them this was one of several projects, while for me it was an all-consuming project. This is likely to give them a different and more distanced way of viewing the project and its outcomes. In addition, the conclusions can also be tested by others. The Kenyan pilot project in Ikisaya can be critically scrutinized by others, although changes over time might lead to different situations. It is also possible to approach various actors who have been involved in the transfer process or have observed the same activities as analyzed here, although few of them have seen all the details that I have observed through my role as coordinator.

Some of the data were collected and analyzed in cooperation with team colleagues, including engineers, as mentioned in Chapter 1. This was important in order to get a broad and deep understanding of the solar energy cases, including the technical aspects and how these interacted with the social.

4.1.5. Analysis and presentation

Analysis should be an iterative process between ideas and data (Hammersley and Atkinson 2007). Ideas emerge from experience in the field, theoretical and empirical literature, and from preliminary analytical reflections on the data. The ideas are confronted with the data, and thereby changed, and new ideas are confronted with new data or new ways of understanding existing data. Such iteration between ideas and data is related to so-called grounded theorizing, which is as a way of working with data, of any sort, in order to generate and develop ideas (Hammersley and Atkinson 2007). Grounded theorizing is partly a reaction against hypothesis testing "where ideas are taken from the literature and then tested against the data" (Hammersley and Atkinson 2007, p. 159). Although this research is not typical grounded theorizing, it has similarities with it, because this research process has included such movement back and forth between ideas, including theoretical concepts, and data. Theory has been used in order to get ideas about what might be going on in the cases, and the cases in turn have shed light on the understandings provided by the theories.

Even though this research is guided by theoretical approaches as well as empirical literature and practical experience, it also has an open approach. For instance, the framework of analysis presented in Chapter 3 covers all kinds of relevant aspects, in an open, non-exclusive way, aiming for a holistic and deep understanding. In addition, since it is not possible to mention or anticipate all potential factors that can play a role for the studied phenomena, the research has to be open for any kind of results. As suggested by Flyvbjerg (2006), phenomena should be explored firsthand instead of reading maps of them.

One strategy for increasing the quality of the analysis is to confront ideas with real world challenges, and to let the analysis mature over some time. A combination of different types of data is also often important. For instance, the analysis of the first research question in this dissertation has been an iterative process between pre-conceptions, literature, data of several kinds and practical experience, going on over several years, and gradually increasing the understanding. It started with the analysis of the Indian solar energy examples (and reviews of literature and other information about relevant energy models), continued with the assessment of the relevance of the Indian ideas for Kenya, development of the Kenyan model and the analysis of the emerging case in Kenya and its relevance for other instances. The practical work has constituted steps in the academic analysis and has been a strong eye-opener for what kinds of factors that can influence village-level energy systems.

Another strategy that can be used in order to increase the quality of the analysis is cooperation with other researchers, either by doing the analysis together, discussing the findings, or sharing comments (Patton 2002). According to Sæther (2010), two researchers should cooperate on the whole research process, because this makes the interpretation more robust through discussions of field experience and interpretations. This has been experienced as fruitful during the case studies in India and Kenya, both with social scientists and practitioners in the team. The discussions were especially vigorous on the interpretation of data from the local level collected by two interviewers together, and this led to further reflection upon the material. This is what (Patton 2002) calls triangulating observers. Cooperation with other researchers and practitioners can also make it easier to obtain data through different methods and on different aspects. In this study, it became possible to conduct quantitative surveys due to the cooperation with others, as complementary methods to the main, qualitative approach.

A third person presentation of my actions is used in this analysis. This is in order to distinguish between the kind of actor I was in the studied case (as part of the action research), and being an analyst of the case. In most of the description I do not distinguish between my own actions and those of team members, because most of my work was carried out in close cooperation with others in the team. Therefore, when referring to "team members", it might be about me or any other team member. In those situations where it might be important to show how leadership was conducted, due to its impact on how the process unfolded, I distinguish between "the team leader" (myself) and other team members.

4.2. Part one of the research: Case study in India

The case study in India was carried out during the first and second year of the project period. In a case study, the researcher attempts to view a social unit as a whole, and organize data around this unit of analysis in order to answer the research questions (Mitchell 2000). The unit of analysis was the energy model with its actors, organization and technical solutions and how it worked in the various villages, including relevant factors outside the local level as explained. A case study allows investigators to keep the holistic and meaningful characteristics of real-life events in order to understand how and why social processes develop (Yin 2013).

Solar mini-grids in the Sunderban Islands in West Bengal were seen as a promising model for the future, and thereby a case that could provide relevant knowledge on how village-level power supply can become possible. The mini-grids were located in remote, poor villages and supplied electricity to households and other customers in such places. These villages could be representative for places in different parts of the world where the whole or most of the population does not have access to electricity. Such places have geographical, socio-economic and political differences, but have similarities in the need for lighting and other electricity services. Such places also typically have a general problem of poverty and marginalization, although the gravity of the problems will have some variations. By selecting villages in India with such general characteristics, and with functioning power provision at the village-level, it was anticipated that the research findings on the power provision could be relevant for villages in Kenya and in many other countries, and that it could be possible to transfer the energy model studied in India to Kenya with some adaptations. The further analysis shows how the differences and similarities in contextual factors influenced the transferability of the Sunderban mini-grid model to Kenya.

The fieldwork on the Sunderban case had three parts at three geographical levels – at the national level in the Indian capital city, at the state level in Kolkata (earlier Calcutta), and at the local level in the Sunderban Islands (see Figure 6 below). The data collection started with the national framework conditions, before the state level programs. The fieldwork in the villages followed before collecting some more information at the state level. A quantitative survey was conducted a few months later. Policy and planning documents and statistics were obtained at all three levels.

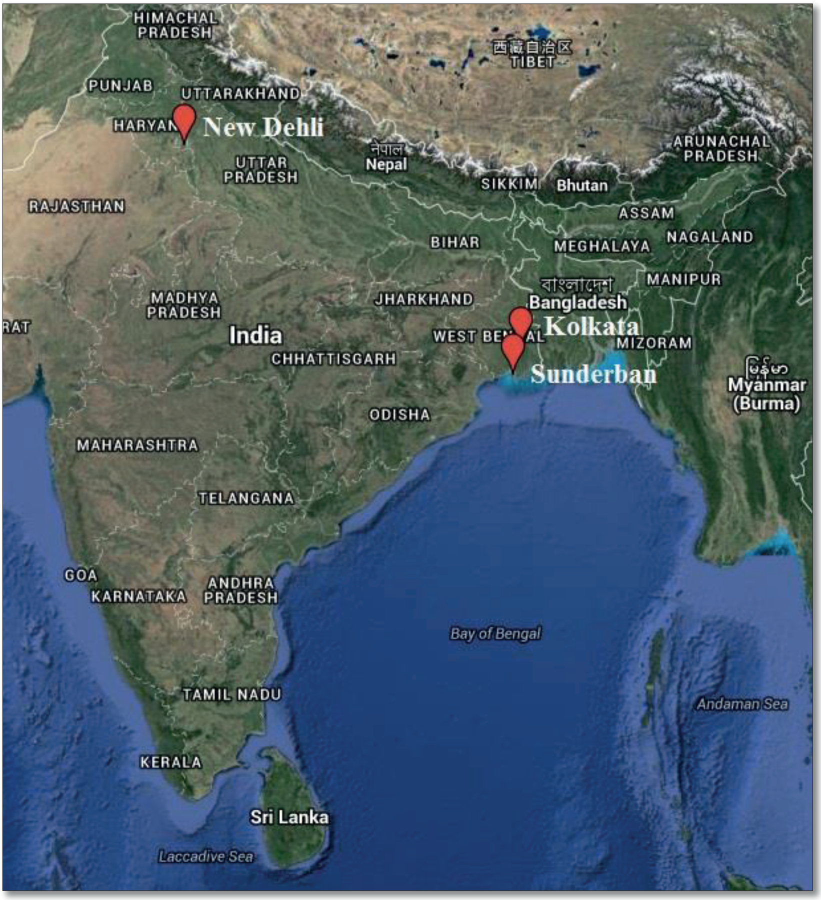

Figure 6. The fieldwork sites in India: New Delhi, Kolkata and the Sunderban Islands. Source: Google maps.

4.2.1. Fieldwork in New Delhi

The purpose of the fieldwork in New Delhi was to understand which parts of the national policies and regulations that were relevant for the kind of local case studied. It was seen as important to interview people with different points of view. The seven informants were officials in the Ministry of Power, Ministry of New and Renewable Energy, technical and other experts on solar energy as well as other energy supply in India, and relevant NGO representatives. I conducted interviews in cooperation with a sociologist on the team.

Some of the informants had been identified during the fieldwork for my m.phil. thesis in 2003, some were identified by the Indian research partner and others were suggested by informants. All informants were selected due to their involvement in and knowledge about off-grid electricity supply in India in general and the Sunderban projects in particular. Some of them had been involved in the facilitation and financing of the projects and others had visited the projects and had views on the models used and how future models should be designed. Several informants had expertise on national framework conditions and policies for off-grid, renewable energy supply and how they had changed over the time period relevant for the Sunderban projects. Policy documents and academic literature on the Indian electricity sector were important background documents and complementary data for the interviews.

4.2.2. Fieldwork in Kolkata

The purpose of the fieldwork in Kolkata, the state capital of West Bengal, was to get insights in the planning and implementation strategies used for the solar mini-grids in the Sunderban Islands, reasons for the socio-technical designs, and the actual working of the power provision. Information on how the national policies and regulations influenced the Sunderban projects was also obtained from the implementing actors at the state level. Key informants were the former leader of West Bengal Renewable Energy Agency (WBREDA) and an official from the same organization. The first had been the visionary and driving force for the development of the projects and the second was responsible for sustaining and maintaining the projects. Other WBREDA staff was also interviewed. An informant represented an NGO that worked on another solar power activity, and two suppliers of technical equipment for the power plants were also interviewed.[17] A workshop and field excursion for team members and Kenyan guests gave additional opportunities to interact with Indian solar energy experts who had first-hand insights in these or other relevant village-level solar power projects in India.

The documents obtained at this level included overviews of the solar mini-grids, the technical details, installation date, location, customers connected, and contractor companies involved. I carried out my fieldwork at this level in collaboration with two social scientists (a sociologist and an anthropologist) and three practitioners in the team (including a Kenyan and a Norwegian engineer).

4.2.3. Fieldwork in the Sunderban Islands

The third part of the fieldwork in India was carried out at the local level. The purpose of the fieldwork in villages was to understand the actual working of the mini-grid systems and access to electricity services for different groups, as well as the socio-cultural and geographical context. Solar power supply systems had been implemented as governmental projects in 17 villages in the Sunderban Islands from 1996 and onwards. Six of these systems were selected for the research, based on variation in time since implementation, size and geographical location. The selected power supply systems were in the villages Natendrapur, Khashmahal, Kaylapara and Mrityunjoynagar on Sagar Island, and the villages Bagdanga and Baliara on Moushuni Island. The model for electricity provision was mostly the same, but with local variations.

[17] These were Ramakrishna Mission Ashrama, Environ Energy Tech Service Ltd. and Agni Power & Electronics Pvt. Ltd.

Qualitative, semi-structured interviews were conducted with households, members of local energy committees and local operators of the power plants. Some of the selected households had an electricity connection (and/or solar home system) and others had not. The perceptions of the solar mini-grids of these two kinds of groups could then be compared. Both men and women were interviewed in their homes, although women were overrepresented because they tended to be the ones who were at home during daytime. Most of my interviews here were conducted together with an anthropologist in the team, and some of the data included was collected by her alone, while I was visiting other informants.

The observation in the villages consisted of visits in power plants and observation of the operations as well as use of electricity there, as well as interactions between local operators and community members. Some of the visits in power plants took place with five other team members, including engineers. Activities in markets, shops and households were observed, including the use of electricity in market areas after dark. Signs could be observed of how the use of electricity in the communities worked differently than stated by the rules of the power plants.

4.2.4. Survey in four villages

A survey was conducted in June 2010, four months after the fieldwork, among key institutions and 200 households in selected villages. The purpose was to follow up and quantify some of the findings from the fieldwork, for instance how many people have light in their kitchen. The survey was carried out in four of the six villages studied earlier, in the islands Sagar (Kaylapara and Khashmahal villages) and Moushuni (Bagdanga and Baliara villages). In interaction with the anthropologist in the team, I drafted five sets of questionnaires for: General information, households, commercial/business, schools and health centres. Various team members (social scientists and technical experts) also contributed with ideas for questions for the survey questionnaires. The processing of the data was done by the anthropologist, and the results are referred to as Winther (2014). Additional data was collected by master students during 2010 and 2012 (Andersen 2010, Vognild 2011, Huseby 2012), and through my communication with informants in Kolkata by email and through an Indian research assistant.

4.2.5. Overview of the data on the Indian case

The following table gives an overview of the data collected for the case study in India.

Table 2. Data collected on the Indian case.

Informants/source of data	Method for data collection	Reason for using the method
Experts and policy makers in New Delhi	7 semi-structured interviews, public documents obtained	Understand the relevant national policies and regulations, and how national level actors viewed the projects
Experts in Kolkata	4 meetings and semi-structured interviews, repeated email communication, project documents obtained	Get the implementers' experiences and project documentation
Local power plant operators	7 semi-structured interviews (men)	Get the experiences of those involved in daily operations
Local board members	6 semi-structured interviews	Get the experiences of people involved in management of the power supply
Households in six villages	18 semi-structured interviews (13 women, 5 men)	Get the experiences of the users of the electricity
Households and businesses in six villages	15 informal conversations (11 men, 4 women)	Get the experiences of the users of the electricity
All kinds of relevant details	Observation in villages, power plants, businesses, schools, homes	Observe practices related to the electricity use, and characteristics of the socio-cultural context
State level offices in West Bengal	Statistics on registered customers and tariff payment, letters, tenders, and contracts	Get number of customers in each village, and compliance of paying tariffs. Understand the roles of suppliers and contractors for the operation and maintenance
Households in four villages	220 survey interviews	Quantify some findings of the qualitative data
Indian solar energy experts	Notes and presentations from workshop	Get the Indian experts' explanations of various cases of solar power supply in India

4.2.6. Organization and analysis of the data collected in India

The interviews and observations were documented by taking comprehensive field notes. Most interviews with key informants were also tape-recorded and transcribed. Team members shared notes and interview transcripts, discussed interpretations, and worked together on analysis and the writing of a report and paper as part of the analysis. I led and coordinated the teamwork on analysis.

An underlying pre-conception before the study in India was that the case represented a "success story". This was based on previous literature and descriptions heard during some years before the study. The fieldwork led to a gradual replacement of these initial interpretations with a more nuanced picture. Continued communication and iteration between observation, household interviews, operator interviews and meetings with implementing actors gradually gave better understanding of the case. The local variations and similarities among the six villages made it possible to catch sight of a multitude of social and technical factors that had shaped the local power supply and how it worked for people. Moreover, the efforts to get the points of view of a variety of actors gave significantly more and better insights than what could have been obtained by only interviewing the key informants who knew all the power plants, although these informants were certainly important.

The combination (triangulation) of interviews and observational data and use of various background documents as well as cooperation and discussions in the research team served to provide a good understanding of the cases. It was possible to discover weaknesses of various parts of the data, and further investigate and scrutinize inconsistencies in the data material. The tacit knowledge and long-term experience of the implementing actors was not likely to be fully accessed, but the last parts of the data collection showed signs of "saturation" – there were few additional aspects that came up.

4.3. Part two: Action research in Kenya

The action research in Kenya was initiated in 2009 and the solar power provision in a village started operating in March 2012. The research can be divided into two different phases: Before and after the start of the solar power provision. The research, follow-up and dissemination has continued up to the present (2015). The specific place for the action research in Kenya, Ikisaya village, was selected by the team as part of the research process, and the reasons for the selection is therefore treated in Chapter 6.

The research in India had been characterized by a coordinated, coherent research activity, concentrated in time and providing a concentrated analysis. The action research in Kenya was explorative, longitudinal and adapted to research needs and practical needs. It can be seen as a collection of research activities and practical planning carried out with a common purpose. During my visits in Kenya, due to research and action going on over a long time period, I moved between being present in the capital city Nairobi and remote villages, and visited the district and county level offices briefly there between. These sites are shown in Figure 7 below.

Underway in the research process I interacted with government officials and various other actors in the renewable energy field, nationally (in Kenya) and internationally (including Norway and India) both with team members and alone. This interaction was both a part of the practical planning of a pilot project in Kenya and sharing of results, and a part of the data collection on the framework conditions for off-grid solar power plants.

Figure 7. The main sites for the fieldwork in Kenya: Ikisaya village in Mutito District, Kitui county, and the capital city Nairobi. Source: Google maps.

4.3.1. Data collection in Kenya before start-up of a village power plant

The research activities before start-up of the power provision in a village were organized according to the same framework of analysis as the research in India. However, since no electricity supply was yet in place, the main focus in this part was on the mapping of energy needs, the understanding of the socio-cultural context including people's livelihood struggles and everyday life, as well as other relevant framework conditions, both at the local, national and international levels. The results obtained on these aspects were crucial for the development of a village-level solar power supply model that could fit in this place and country. The team alternated between data collection and analysis on the one hand, and planning and cooperation with community members on the other hand, in an iterative process of developing the model. This process is explained as part of the analysis.

4.3.1.1. Quantitative survey

An early part of the data collection in Ikisaya was a quantitative survey conducted in Ikisaya (in 2010) to get information about people's expenditures on energy as well as other data. The results from the survey were used as a starting point for the qualitative research, indicating themes that might be important to investigate in depth. The survey was a team effort coordinated by a Kenyan team member and me. Two Kenyan master students carried out the 70 interviews in Ikisaya village, using interpreters and drivers from the village. The selection of informants for the survey was based on wealth distribution, gender and representation of different parts of the settlement, schools, businesses and offices. The survey data was analyzed by the Kenyan team member, who extracted information from the material on request from me and other team members.

4.3.1.2. Observation, focus groups, meetings and informal conversations

A part of the understanding obtained of the village community has come from the long-term interaction with people there through five visits for research and planning of the pilot project before the start-up phase, during different seasons. I met a large number of people during these visits, when staying in a home and when meeting with the general public in meetings organized by the village leaders. Some people expressed views and questions about the upcoming solar project. Meetings were held with the leaders group, the sub-chief (the local administration), the school committee, the water committee, the head teacher, other teachers, and the local administrations in neighboring villages. These meetings were good arenas for obtaining key information about the geographical area. A large number of informal conversations were held with people, partly in English, and partly by the help of translators of Kikamba language. I was staying around in the market area, in shops, in churches and in public meetings to observe some of village life. I took notes on the interaction with people in the village, and I worked with local research assistants to collect GPS points for a map of the village (included in Chapter 7).

Group interviews were conducted with various community groups (goat groups, farming groups, soap making groups, etc.), of which some consisted of men, others of women. These interviews were carried out in cooperation with an anthropologist in the team. She also conducted semi-structured interviews in households. Due to my role as a project leader for the solar power project, I chose to let other team members do household interviews, although I gave inputs, coordinated, and took part in it. A few months before the power supply started operating I conducted a small survey (18 respondents) distributed on different geographical areas and wealth levels in the village, on people's expectations for the electricity provision, to be able to compare the expectations with their future views on the functioning of the electricity provision and quality of the services. Local research assistants gave inputs on the research questions, and carried out the interviews.

4.3.1.3. Data collection on the Kenyan framework conditions

The investigation of the Kenyan framework conditions took place gradually over time, through a combination of interviews, interaction with various actors in the renewable energy field, and information and updates by Kenyan team members who had first-hand information about policy changes and discussions. The Kenyan policy framework came in as a natural part of the discussions on the design of the pilot project, often brought up by Kenyan team members. To some extent, I also monitored other kinds of framework conditions, like international trends in the solar PV field, through interaction with industry actors in workshops, meetings and price bids when solar PV equipment was purchased for the Kenyan project.

4.3.2. Overview of data on the Kenyan context

The following table summarizes the data collection at different geographical levels for the research conducted in the first phase of the action research in Kenya. Some of the data on the national framework conditions mentioned in the table were collected after the solar project started.

Table 3. Overview of data on contextual factors in Ikisaya village and national framework conditions for use of off-grid renewable energy in Kenya.

Informants, source of data	Method used for data collection, timing	Reasons for using the method
Government official, local staff and board members at different power plants	Visits to three existing off-grid energy supply systems in Kenya and conversations on national framework conditions, October 2010	To see some village-level power plants with diesel generators
Government officials, village representatives	Field visits to three potential villages for the pilot project, October 2010	Selection of village in Kenya
Kenyan government official (engineer)	Meetings, phone calls, semi-structured and unstructured interviews 2009-2014	To follow new activities of the Kenyan government on solar PV over time
Energy experts and policy makers	24 other meetings with experts and policy makers in Nairobi, 2007-2013	To follow the activities by the Kenyan government over time and inform about the Solar Transitions plans
Households	Quantitative survey in Ikisaya village, 70 survey interviews, June 2010	To map energy needs and local conditions
Households	Overview map made by county office, October 2010	Location of all households in Ikisaya
Households	Collection of 300 GPS points, making of map of all households in the village, November 2010	Location of all households in Ikisaya
Individual household members	Group interviews with 8 community groups in Ikisaya village, March 2011	Understanding of energy needs and local livelihoods
Individual household members	Survey on expectations before start-up of electricity supply,18 survey interviews, January 2012	Comparison with later situation
Local leaders, administration, school and water committees, head teacher	Meetings and informal conversations. October 2010 – March 2012	Understanding the community and development of model for power supply in Ikisaya

4.3.3. Data collection on the Kenyan project after start-up

The second phase of the action research in Kenya started on the opening day of the Kenyan solar project in March 2012, and the purpose was to analyze and learn from the results of the pilot project, and adjust and improve the project. This research was a combination of traditional case study research and action research. It was traditional social science research in the sense that I collected a variety of data, on a social unit, the Ikisaya Energy Centre. It was action research in the sense that I was central in creating the case and continued to take part in improvements of the Centre. I sought similar insights on a local, off-grid electricity model as the research in India, but through continuous monitoring over time. Research findings were used in order to contribute to improvement, and to understand the effects of the practical changes made underway. Sharing of results with the government and other interested actors was also part of the work, as well as documentation of extended consequences in Kenya.

The fieldwork and data collection on how the Kenyan project worked in practice consisted of a variety of methods. Participant observation and practical work to improve the project were combined with collection of financial reports and other statistical data from the operations of the energy Centre, and regular phone calls with the staff at the Centre. The phone calls were a combination of common discussions on the progress of the Centre and data collection for the academic analysis. The participant observation included meetings with the local staff and board during the visits, involvement in practical work like cleaning the rooms at the Centre, helping to do typing jobs at the IT room, and staying around at the Centre for several consecutive days, at different times of the year. The purpose of the meetings was to discuss with the local actors on our joint work to make the project function in a long-term perspective.

The various visits in Ikisaya in this phase lasted for between two and ten days each time. It was more important to visit at different points in time than to stay for extended periods of time. After the visit during start-up of the solar power project in March 2012, the following visits were in April, June, August and October 2012, and in February 2013, which was my last visit so far (this was 23 months after implementation). Important informants in this phase, in addition to local staff and board members of the energy project, were the local administration, school representatives, customers at the energy centre (households and small businesses), non-customers, government officials at different levels (including the national level), NGOs, businesses and experts within the field of renewable energy in Kenya.

I received the detailed financial results from each month of operation by phone nearly every month for two and a half years. The financial reports provided useful data because they showed many sides of how the energy supply worked. For instance, they showed how much and how often people used the different electricity services. (There were small errors in the financial reports some times, but they showed the main situation and trends.)

Despite continued involvement after the start of the electricity provision, I became more of an observer than before. The role I took in the phase after start-up of the electricity services is similar to the social scientist doing "trailing research", where the researcher first enters a workplace or other social unit and works with the people there to facilitate common learning processes and changes. Later the researcher withdraws from active participation and concentrates on the observation and analysis of the ongoing change process (Olsen and Lindøe 2004). When the researcher goes from being an activist to being an observer, this might create confusion among the members of the studied organization or community. The change in my role was not fully as sharp as this, as I was still active in creating change to some extent. Both roles could however influence the way I was seen by community members and what they said and did in my presence. The data collection in Ikisaya was carried out with this in mind.

I did not conduct household interviews or observations in households during this phase, but rather sought data that were less likely to be influenced by my role. I mostly relied on indirect ways of obtaining information about the views of the households. This was possible though frequent information from the staff on feedback they received from customers or others, and through statistics found in the record books at the Centre (in addition to the financial reports). One of the local staff members also took notes regularly over one year on what the community members commented on, asked for and complained about in relation to the energy services. The data show that the customers and others tended to be open about complaints and problems towards the staff, board members, team members (including myself), and other observers. Three master students did qualitative household interviews in Ikisaya for their master theses, the last one in September 2013. These provided additional insights into the household members' views on the project and their ability to make use of the new electricity services available (Mosberg 2013, Berg 2014, Stokke 2014).

I had good access to information on how the Centre worked in practice because I had personal relations to staff members and we shared an engagement for the Energy Centre as well as a concern for how to make it able to survive and prosper, together with other team members. There could still be some information that would be kept back, especially in order to avoid making me disappointed. However, my general impression is that the conversations were fairly open and that many concerns were openly shared.

4.3.4. Overview of data collected on the Ikisaya solar power project

The following table gives an overview of the data collected after the Kenyan pilot project started operating. Most of these data were collected independently of team colleagues, while they sometimes assisted in order to obtain documentation. For instance, one team member analyzed the detailed statistics of the daily operations copied from record books by the staff at the Energy Centre in Ikisaya, and another compiled financial results into overviews and graphs.

Table 4. Data collected on the Kenyan pilot project after start-up of operation.

Informants	Method used for data collection, timing	Reasons for using the method
People in Ikisaya and three surrounding villages, customers and staff at the Energy Centre.	Field notes based on observation in and around the Energy Centre, 6 visits in Ikisaya over the first 18 months of operations.	Monitor and understand how the energy model works in practice and changes over time, and how the electricity services are used. Continue the practical development of the model.
Energy Centre staff	Financial reports from Energy Centre operations from 18 months, bank slips, minutes from staff and board meetings. Statistics on the details of daily use of the services by the community members.	Understand how the energy model works and changes over time. See how people use the services, and how this changes over time.
Staff and board, sub-chief, chiefs, the public in Ikisaya	Notes from 15 meetings with local staff, board, sub-chief, chiefs, and the public in Ikisaya after implementation. Two recordings from meetings where I was not present.	Hear the views of various actors at the local level, make plans on how to improve the pilot project. Understand how contextual factors at the local level influence the project. Continue the action research and innovation process.
Staff	Notes on more than 50 phone calls with staff members of 30-60 minutes, month 8 to 28 of operation	To document the long-term discussions on the situation and ways forward.
Staff, community members	10 pages of typed notes written by staff members on their interaction with community members, minutes from 11 staff meetings, 4 board meetings and 5 member meetings.	To understand challenges met by local staff. To understand people's views on the services and rules for use, and changes over time.
Kenyan government officials, suppliers, NGOs and international aid agencies	Workshop organized in Nairobi, 56 participants from organizations and companies. A smaller workshop organized for government agencies working on off-grid solar PV.	Get views on the suitability of the energy model for government energy work and other actors' work.

4.3.5. Organization and analysis of data on the action research in Kenya

For the practical purpose of improving the model, the data were analyzed continuously as they were collected. Some of the analysis for practical purposes was only in the form of thinking and discussions on observed situations only, based on notes or statistics. For the academic purposes, the data were analyzed by comparing and combining (triangulating) the different kinds of data from the different points in time to provide a larger picture of how this local, socio-technical system worked and changed during its first two years of operation. The analysis was systematized by the case-study framework presented in Chapter 4.

4.4. Part three: Documentation and analysis of the overall transfer process

The purpose of this part of the research was to analyze the whole process of transferring innovations from India to Kenya in order to describe the way it unfolded, identify its main characteristics and how it led to the observable outcomes. The research in this phase has some similarities with "process tracing", which is a research method that attempts to trace, backward in time, processes that have led to an observed outcome, and to understand the reasons for the outcome (George and Bennett 2005). The research design for this dissertation instead provided an opportunity to trace the process as it came into being.

4.4.1. Data collection on planning, considerations, actions and outcomes

The analysis of the five-year long process built on a variety of data sources and methods. In addition to the data material described above, the process was documented as continuously as possible by notes, project documents, e-mails between team members, meeting reports, proposals for funding support for technical installations and other data. Other data were letters to the village community, and informal conversations with the team members and with the Kenyan guests during the study tour to India. Interviews and group interviews with team members provided the team members' reflections upon the way in which the strategy worked. The data show the communication in the team, the crossroads, the considerations and decisions made by the team, the cooperation with the actors outside the team, the dilemmas and uncertainties, the optimism and disappointments. The data also show the different and evolving ideas for the Kenyan pilot project.

The team members provided their reflections on how the transfer activity worked out, both during interviews, meetings and informal conversations. My role as a leader most likely influenced what the team members told me, and the most critical viewpoints may not have been expressed. However, several of the team colleagues were frank on disagreements. In the formal, annual reporting for team members I requested that they answered specific questions sent to them as part of the report template. Most of the team members put an effort into reflecting on the questions and formulating some key experiences from the process and gave remarks on what the process looked like from their side. However, it was the real discussions in the team's meetings in India, Kenya and Norway and the real, common work that gave the most important data on how they related to the transfer process. Moreover, hundreds of emails document the long-distance cooperation in the team on research and practice. Minutes and notes from the project meetings and fieldwork describe the face to face interaction.

There are different ways of writing field notes for documentation of an action research process. They can be similar to common field notes, documenting what is said, seen and heard, but they can also be reflections on the research process and the interaction between the researcher and others, and give signs of power relations and other aspects that influence the knowledge production. According to Mansvelt and Berg (2010), notes taken on thoughts, observations, emotions, and interpretations that occur during the research are signifiers of complex relations that influence the research process. The notes can thereby provide insight into the researcher's own speaking position and how it is articulated, challenged and modified through the research journey. My field notes are doing both. Some of the notes are more like an outlet for concerns on the way forward than on describing situations. Such notes show some of the difficulties encountered underway in the practical work and reactions on other people's suggestions and actions, and exemplify the contingent and open-ended nature of innovation efforts.

4.4.2. Overview of data on the transfer process

The following table shows the data I collected in order to document and analyze the process.

Table 5. Data on the process of transferring innovations between India and Kenya.

Informants, source of data	Data collected	Reason for collecting these data
Team members, Kenyan guests for the study tour in India	Minutes and reports from study tour to India, notes on informal conversations	Document the experiences of the participants of observing the Indian examples
Team members, other cooperation partners	Notes and thorough minutes from 10 project meetings and 4 workshops	Document the activities, discussions and considerations underway in the process
All involved actors at the local level	Reports on field visits during different stages of the practical planning process and data collection	To document interaction with the community
Team members	Notes kept from almost all phone calls and Skype calls	Document discussions on research and practice
Own notes and reflections	Personal notes on the different stages of the process (on planning of the practical project, challenges, concerns, ideas, decisions, and reflections on the process)	Document characteristics of the process as it unfolded
Team members and other involved people	Notes on communication within the team	Document discussions on research and practice
Team members	15 semi-structured interviews with team members during 2010 and 2011, and informal conversations during the whole project period	Get the team members' views on how the transfer process worked, at different times
Team members	Three group interviews with the team in different project meetings in Kenya and Norway in 2011, 2012 and 2013	Get the views of the team members on how the transfer process worked at different times
Team members	Team members' reporting: questions answered in the project reporting, four years.	Get the views of the team members on how the transfer process worked at different times
Team members	211 emails sent by me to groups of team members on coordination, collaboration and information	Document discussions on research and practice
Own e-mails during project coordination	A large number of e-mails sent by me to individuals in the team	Document discussions on research and practice
Team members	A large number of emails received from team members	Document discussions on research and practice

4.4.3. Organization and analysis of the data on the overall transfer process

The personal field notes taken during the first two years were typed up from the notebooks. The rest of the field notes are in handwritten form and were copied and systematized in ring binders. Some of the discussions in the team and with village committees were recorded, and some of these were transcribed and combined with own notes. Those recordings not transcribed have been listened to when needed to check the notes from the same situations. The data were coded on paper by using colors and key words, and revisited during the writing process. Large amounts of notes were taken, and some parts are seen as less important. The most important parts were revisited several times in order to question and reconsider the interpretations. Here, as for the previous parts of the research, it was important to give different interpretations of the data the chance to arise and be considered (Patton 2002, Hammersley and Atkinson 2007, Haugen 2013). The analysis of the process also included the data and analysis of the Indian and Kenyan cases presented above. Team members have read and commented on the analysis. The combination of the variety of data and the direct experience of the process contributes to a balanced understanding, although the involved position as an action researcher can lead to some blind spots, as discussed above.

4.5. Ethical considerations

Two ethical considerations are central in this research. The first concerns research on people in vulnerable situations in Indian and Kenyan villages. The poverty levels there are high, and many kinds of factors create vulnerability. In the Kenyan village the research has initiated change processes together with people and thus influenced their situation, and this influence is not likely to be purely positive. The second consideration concerns informed consent and issues of exposure of individuals and groups.

4.5.1. Research on and with people in vulnerable situations

The overall ethical concern for the research and action was to avoid doing harm. An additional concern in Kenya was and is to contribute to positive change. The kind of change was going to be defined by the community and the team, within the limits of what technology could do, what could be manageable for the community, people's ability to pay for electricity and so on. However, the outcomes could not be known beforehand. Although the village community in Ikisaya embraced the project idea, a heavy responsibility rested on the team, because problems in the project could affect the community members. This was not a unique situation which only applies for an action research project. Within the field of development aid, there is also a large responsibility resting upon project implementers on how to carry out the project in ways that work well for the communities. Moreover, not only in the South, but also in the North, an action research or community project could risk to lead to negative effects.

In action research (as in other kinds of initiatives for social change), ethical dilemmas can arise underway in unexpected ways. It is therefore important to recognize an ethical issue when it arises, so that it can be taken into consideration and addressed (Herr and Anderson 2005). It is not necessarily a negative thing if people meet new challenges. It was here nevertheless seen as important to follow up the project over time to assist the local electricity organization to become independent through experience and gradual learning. It was also seen as important to be completely open about the team's motivation for doing the research and practice, express concerns and uncertainties underway, give detailed information, discuss all matters with the local actors, and not take a patronizing tone in any situation. According to Kindon (2010), a key way to manage challenges with action research is to be realistic with oneself, the co-researchers and other stakeholders about what can be possible to commit to within the available time and resources.

It seems like the project has not created many stress-factors for community members, apart from an episode of tension in October 2012, which was addressed by the research team, as described in Chapter 9. However, it cannot be claimed that there are no negative effects. For instance, there are still many people who do not directly benefit. It can be argued that it would be more ethically sound to do data collection only, without any practical intervention as part of the research design. However, one can also question the ethics of repeatedly doing research in poor remote communities without being able to follow up on the research findings. When researchers do in-depth qualitative interviews on issues that have importance for the informants, this can be a positive experience for the informants – an opportunity to express thoughts and concerns and reflect on one's own situation. Qualitative methods are characterized by empathy, which is important in order to understand the informants' life circumstances (Patton 2002). Such interaction can at the same time create expectations that the outside world is now understanding the informants' problems, and disappointment when nobody comes back in order to address these.

During analysis and publication of findings, it is important to avoid generalization and stigmatization of people in vulnerable, difficult situations (NESH 2006). It is also important to show the strengths and capacities of such groups, and their struggle to cope with and change the situation. Many researchers who work in developing country contexts are conscious about this and draw attention to the complex livelihood strategies and capacities of people who face challenges that might be poorly understood by most outsiders (Eriksen et al. 2007). People are in this way seen as change agents who are affected by the structural constraints that produce vulnerability.

4.5.2. Informed consent

The informants in India answered positively when they were asked about their willingness to be interviewed for this research. The team came with a genuine interest to learn from the informants' experiences in pioneering projects. In the Kenyan case, the attitudes were even more positive, both at the local level and at district and national levels. Oral approval was obtained from community members, while approval letters were received from village, district and county authorities after providing information about the project through meetings and letters. Approval from Norwegian Social Science Data Services (NSD) was also obtained, and the routines set by NSD has been followed, including for the storage of data. Sensitive, personal information has not been collected.

Anonymization of the village in Kenya has not been seen as meaningful because the name has been published on websites and in workshops. The goal of making a demonstration project (which has already led several visitors to Ikisaya) also implies that it must be possible to identify and travel to the village. Those individuals who can easily be identified because of this are the former and current staff members at the energy centre. So far, the project seems to have been something that they have been proud of representing. The staff members have acquired new skills; they have important jobs in the village or have moved on to other jobs, they have regular salaries and have had an impact on how the electricity services are given. They are in a less vulnerable situation than many others in the community, they receive guests and researchers and they communicate with the research team in case of problems. However, I have attempted not to uncritically describe everything they have said or done. This would be misuse of the trust they have shown me during our collaboration. The way in which they will perceive the descriptions has been considered, and they have been consulted on potentially sensitive themes.

A related issue is the risk of political influence on research in a community. A research activity might be influenced by the background and interests of key informants, or other individuals who might be important facilitators and contact persons in the field. In action research, this can have an impact on the researcher's understanding of the studied case as well as on the practical outcomes of the research process and the way it takes different people's interests into account. This can influence the way the practical project works, and thereby the knowledge generated through analyzing it. Also in this research, there have been situations where key contact persons or informants might have done something for their own personal interest in addition to working for the best of the common project. This has been pointed out by community members, project team members and observers, and it has therefore been possible to make corrections. Such challenges have been openly discussed within the project team and also with local actors, and the academic analysis takes into account the views of people from different groups and economic interests. The longitudinal action research has shed light on the different views and interests but it can still not be claimed that the local power dynamics are fully understood.

4.6. Transferability of findings

The insights generated on the Sunderban and Ikisaya cases of village-level power provision are not *directly* transferable to other situations, as this whole dissertation illustrates. However, the findings increase the understanding of factors that may influence the work on such electricity provision, and is likely to have relevance in many places and countries, as will be explained in the discussions and conclusions. There is a paradox between appreciating the potential of a qualitative research approach to provide a rich understanding of cases in their context, and the idea that knowledge produced through such a contextual approach can actually be relevant in a different place and country. The analysis will show how this paradox played itself out in the team's effort to do an actual transfer exercise based on a case study.

Also, strategies for transfer and exchange of ideas and knowledge, as well as efforts for socio-technical innovation, might come about in several ways, and this research explores one possible route. In a new case, there might be different actor constellations, different emphasis on social science research as part of the transfer strategy, different goals and modes of collaboration, and different background knowledge. However, the knowledge generated on the transfer process analyzed here is likely to provide new understanding of factors that can play a role also in other cases of spatial in transfer of innovations.

The dissertation aims at careful, contingent, analytical generalization, where the empirical findings from cases may support, add to, or question existing theoretical and empirical insights from similar kinds of phenomena. Knowledge is context dependent (Flyvbjerg 2006), and a rigorous presentation of the research findings in context is important to enable others to assess the basis on which the conclusions are drawn as well as their transferability to other related cases (Gomm et al. 2000, Lincoln and Guba 2000). The degree of relevance for a new case has to be assessed every time, through empirical investigation of cases in context, the reason being that "…there are always differences in context from situation to situation and even the single situation differs over time" (Lincoln and Guba 2000).

Chapter 5: Analyzing the Indian case

This chapter presents findings on the different dimensions of the Indian case as outlined in the framework of analysis: 1) The role of framework conditions at the regional, national and international levels (dimension A), 2) The role of socio-cultural and geographical context where the projects were implemented (dimension B), 3) Local energy system design and how it was shaped (dimension C), 4) Actual working of the system and factors that influence it seen from different actors' perspectives (dimension D), 5) Actual access to electricity services for different groups and its reasons (dimension E) and 6) Replication of the system (dimension F). The different parts of the chapter show how the different dimensions are connected to each other.

The research on this case was guided by two questions; "what can the Indian case say about how village-level solar power provision can be socially organized in order to become viable and useful?", and "how can the case be understood in a way that makes it possible to transfer the solar mini-grid model to Kenya?" The analysis thereby contributes to both levels of research presented in this dissertation. At the first level, the case study provides insights in the social organization of village level electricity systems. The study therefore illustrates the complexity of learning processes that may be generated by such experiments.[18] At the second level, the case study explores how a local, socio-technical innovation embedded in a specific societal context, can be studied with the purpose of transferring socio-technical designs, knowledge and experience to different contextual conditions. At the time of the study, the research team had already for some time worked on the planning of the pilot project in Kenya which was supposed to be a solar mini-grid, and was strongly motivated to learn as much as possible from this example of solar mini-grids in India. (For a basic description of solar mini-grid models, see Chapter 1.)

5.1. The role of the national framework conditions

National level policies and programs enabled and influenced the pioneering solar mini-grid projects in the Sunderban Islands, which were developed from 1996 onwards. The project implementer was a government agency at the state level; West Bengal Renewable Energy Development Agency (WBREDA). The agency here established the first solar mini-grids in India, representing a completely new way of using solar power in the country. The implementation of the projects constituted an innovative activity which could be seen as a sustainability experiment, as defined in Chapter 2 (Berkhout et al. 2010).

[18] Some of the material used in this analysis has been published in Ulsrud et al. (2011).

Within the overall solar PV sector in India, it is possible to imagine sub-sectors for off-grid and grid-connected use of solar PV technology. Grid-connected use is emerging in India, and is a different kind of socio-technical configuration with different challenges and opportunities than off-grid use. The first policy for grid-connected solar power in India was introduced in January 2008 (Shrimali and Rohra 2012). Within off-grid use, there are also sub-categories with distinctly different characteristics, including household level and village-level systems as explained in Chapter 1. The activities on solar PV are also closely related to those on other renewable energy technologies, as part of a joint renewable energy sector, often supported by similar policies, and meeting some of the same barriers for becoming widely used.

5.1.1. Challenges of rural electrification in India

The task of providing electricity to all in India remains huge, despite long-standing efforts on electrification by the Government of India (Bhattacharyya and Srivastava 2009, Palit and Chaurey 2011). The number of people who did not have access to electricity in India in 2011 was approximately 306 million (World Bank and IEA 2013). Many of these people resided in isolated communities such as islands, including the Sunderban Islands, forest fringes and hilly settlements, but a substantial portion were also found in already electrified areas (Palit and Chaurey 2011).

Electricity utilities as well as private sector electricity providers have been reluctant to provide grid extension in rural areas despite various policy plans and programs because it is costly, gives low revenue and high losses of electricity (Bhattacharyya 2007, Nouni et al. 2009, Joseph 2010).[19] However, grid extension has reached an increasing number of villages, up to more than 90% of the 570,000 villages in India (Palit and Chaurey 2011). Despite this achievement, the actual number of households connected continues to be low. The definition of an electrified village is that basic infrastructure such as distribution transformer and distribution lines are provided in the inhabited locality as well as the hamlet where it exists, the electricity supply covers public places like schools or health centres, and covers at least 10% of the households (Palit and Chaurey 2011).[20] Therefore, there is a large difference between percentage of villages electrified and portion of households connected. Reasons for non-connection by households include their financial constraints, the perception that the quantity and quality of the electricity services will be inadequate, and poor reliability of the electricity supply (Palit and Chaurey 2011).

---

[19] Small rural customers impose especially high costs of supply as they are demanding electricity especially during peak hours at a low voltage level (Bhattacharyya 2007). This is because losses of electricity during distribution are high where the power lines are long and the voltage level low.

[20] The definition was changed in 2004 and reduced the electrification achievements for India because the previous definition only required that the grid reached any point within the revenue boundary of a village (Palit and Chaurey 2011).

5.1.2. Government programs and incentives for use of solar PV for power provision

An important factor that made the Sunderban projects possible was the funding support achieved from the central government of India. Already from the outset in 1996, the national framework conditions for use of solar PV technology and other renewable energy technologies in India had an impact on the room for maneuver for the project implementers.

The potential of renewable energy was early acknowledged by the national government of India and led to the creation of a special Ministry for New and Renewable Energy Sources (MNRE) in 1992.[21] The Ministry's initiatives and allocation of funds for various renewable energy programs facilitated the activities in West Bengal and other states, through state level agencies (like WBREDA) which implement policies and programs for the Ministry. The Ministry thereby helped establish system innovation within the use of solar PV technology as well as other renewable energy technologies in India.

The Ministry is still small compared to the Ministry of Power and the Ministry of Petroleum and Natural Gas, which represent the dominating and prioritized energy regime in India. These and other strong and established institutions, maintain and strengthen the conventional strategies for power provision. These are not creating direct hindrances to the off-grid, renewable energy activities, and the latter have also started to become part of the electrification programs of Ministry of Power, through a program called the Decentralized, Distributed Generation program (DDG). However, there is little doubt that conventional, large scale centralized solutions are seen as far more important than the small-scale, decentralized solutions using solar PV or other renewable energy technology. For instance, the interviewed person responsible for decentralized, renewable power provision under Ministry of Power did not see decentralized power provision as important for the huge task of electrifying the remaining un-electrified areas in India.

The work on solar power provision in India started several decades ago. According to government statistics, there are more than 700,000 solar home systems and more than 800,000 solar lanterns in India (around 40 MW installed capacity), in addition to the village level systems (solar mini-grids and solar charging stations, 96 MW installed capacity) (Palit 2013). The statistics do not show how many of these systems are actually working, but according to informants, problems of maintenance and battery replacement have been common.

The support for off-grid solar power supply has been given through various policies and programs. During the early years, the government policy mainly emphasized subsidies and government tenders for purchase of technical equipment. From the 1990s there were also initiatives to facilitate market based diffusion, through micro-financing. A financing agency, Indian Renewable Energy Development Agency (IREDA), was established by the government to administer financing of activities in the solar PV field and other renewable energy through loans with low interest rates. The focus was on solar systems for individual

[21] Worldwide this was the first ministry of its kind. The name was earlier the Ministry of Non-conventional Energy Sources (MNES) (up to 2006), and it built on the Department of Non-Conventional Energy Sources (DNES) started in 1982.

buildings, and WBREDA developed its solar mini-grid model as an alternative to these, but achieved financing from the same sources. The MNRE official interviewed expressed ownership of the projects.

The basis for the recent policies and programs for electrification, including decentralized solutions, is the Electricity Act from 2003. This states that all areas in India shall be electrified, but that some of the areas are not likely to be reached by normal, rural electrification. This is because they are either remote, in difficult terrain or very sparsely populated. These areas shall at least be provided with basic lighting facilities. The Remote Village Electrification (RVE) program initiated by MNRE (in 2001) works for provision of basic lighting systems to all households of such villages (Moharil and Kulkarni 2009). By 2011, the RVE program covered 1.5% of the electrified villages in the country (Palit and Chaurey 2011). Some of the solar mini-grids in the Sunderban Islands were funded from this program.

The Javaharlal Nehru National Solar Mission of the MNRE has increased the activities of the MNRE and the flow of resources into RVE, according to solar PV-experts interviewed in New Dehli. The Solar Mission aims to set up an enabling environment for solar technology by creating policy frameworks, increase the capacity of grid-connected solar power generation, establish favorable conditions for solar manufacturing capability and promote programs for off grid application.[22] Among its targets has been to promote off-grid systems to people "without access to commercial energy", including 20 million solar lighting systems, under the RVE program. The promotion of solar lighting systems is only a small part of the Solar Mission, which mainly promotes grid connected solar power supply through policy instruments such as feed-in tariffs, viability gap funding and renewable energy certificates (Shrimali and Rohra 2012).

Rural electrification is the domain of Ministry of Power, and since 2005 the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) has been the overall program for this. Since then, both grid extension and decentralized, off-grid electricity generation has been included, but the latter is nevertheless a new and small activity for this ministry, seen as intermediate solutions until the grid is extended to these places. After the Ministry of Power got the responsibility for some of the decentralized off-grid electricity generation, there was a fight between the ministries on who should implement off-grid projects, and the MNRE was being marginalized according to solar energy experts in New Dehli. This situation possibly had an impact on how the Sunderban projects were viewed at the time of the fieldwork, both by the implementers, energy consultants and policy makers. They did not seem to judge WBREDA's Sunderban model as a model for the future.

The power sector reform in India in the 1990s had led to increased focus on profitable activities and drive for commercial solutions for electrification. Such ideals were strongly expressed by the informant in Ministry of Power, emphasizing the commercial thinking in this Ministry. The Electricity Act of 2003 had dissolved the vertically integrated utilities and separated the generation, transmission and distribution of electricity as separate businesses operated by large companies, of which the majority is still state owned (Bhattacharyya 2010). Some of them are owned by the Ministry itself. The distribution

[22] Resolution no. 5/14/2008-P&C

utilities are state owned, and a typical problem for these is debt due to unrealistic tariffs and subsidized agricultural connections (Nouni et al. 2009, Bhattacharyya 2010, Joseph 2010).

The opening up for non-state actors is also present in the DDG program of Ministry of Power. There are provisions for license free generation and distribution of electricity from stand-alone and off-grid systems in rural areas and management of rural distribution by local governmental bodies, cooperative societies, non-governmental organizations, franchisees and others (Dubash 2007). Tariffs for such systems are not regulated. It was hoped by the Ministry official and solar experts interviewed that the program could involve the private sector through franchisee models for off-grid areas through competitive bidding with 90% capital subsidy and a small operational subsidy. An informant in Ministry of Power criticized the Sunderban solar mini-grids for not being commercially profitable and thereby not replicable by private sector actors, and he criticized the provision of grants to off-grid power plants in West Bengal through MNRE financing.

This section has identified some of the context that facilitated and influenced efforts to develop new models for solar power supply in India, including the shortcomings of the conventional electricity regime and relevant elements of the socio-technical system (or niche) for solar PV in India. WBREDA's solar mini-grids in the Sunderban Islands emerged from these broader framework conditions in India.

5.2. The socio-cultural and geographical context

Socio-technical innovation must not only be understood in the context of enabling and hindering factors of policies, programs and other elements of the wider socio-technical systems they are influenced by, but also as part of the local, socio-cultural context in the places where they have been implemented (dimension B of the case study framework, see Chapter 3). The Sunderban Islands where WBREDA's solar mini-grids were implemented, are located in the Indian portion of the Sunderban region, which is spread over India and Bangladesh. The islands form the lower part of the Ganges delta. The Indian portion of the Sunderban region is located south of Kolkata, the capital city of West Bengal, and has 1085 villages in 54 islands with a population of 4.5 million (see map in Chapter 4 and map below). When mentioning the Sunderban region or Sunderban Islands, it means the Indian part of the area.

5.2.1. Livelihoods, socio-economic conditions, and political and administrative organization

The main livelihoods of the Sunderban people are agriculture and use of resources available within the forest areas of the Sunderban Islands. The farmers grow rice, chili, coco nuts, vegetables and betel leaves. Important forest products are honey, bees-wax, fish, and thatching materials.[23] Fishery and tourism also plays a role for the economy of the region.

[23] Traditional forest produce is timber, fuelwood and pulpwood, but the cutting of trees has been restricted to reduce erosion problems.

The Sagar Mela is a large, yearly festival in Sagar Island visited by people from all over India, and contributes to larger economic opportunities on this island than on surrounding islands. The tropical, warm and humid monsoon climate shapes the agricultural conditions along with the extreme tide differences and floods of saline water from the Bay of Bengal, sometimes affecting the fertility of the land. Recurrent cyclones also affect people's livelihood struggle in this delta landscape.

There are large socio-economic differences between people, although most families own a piece of land. The people below the poverty line (in India officially called BPL-people) comprises of almost 30-35% of the total population in the region (TERI 2009). The social structure is primarily patriarchal, and men tend to control land and other material and financial assets (Winther 2014).

The settlement pattern is dense in the villages, with several hundred households living within a radius of few kilometers. The cultural landscape in these flat islands is impressively shaped by the hands of the people, changed from a flat plain to a varied surface. Elevated roads have been built widely, some of them also functioning as embankments towards the sea. Many of the families that own land have dug their own pond for harvesting rainwater next to the house, and grow trees around the houses and between the farm fields. Ownership of land, ponds and houses is a sign of relative wealth compared to those without such assets.[24]

Literacy varies between villages, but the average in the two districts that comprise the Sunderban region (South 24 Pargana and North 24 Pargana) is 84.95% and 78.57% respectively.[25] Schooling is mainly administered by the state, while a few schools are private, owned by missionaries or others. The number of schools and colleges has increased over the past few years, and people have given higher priority to education. Health facilities are provided by the government and missionaries, and are scarce. The Sunderban region is described as poorly developed compared to other parts of West Bengal (Government of West Bengal 2004).

The political and administrative organization in the Sunderban comprises of 19 blocks in the two districts mentioned above. The block is the lowest administrative unit of the provincial government. The lowest political unit is the Gram Panchayat, a self-government of elected representatives at the village level. Each Gram Panchayat can cover several villages. For example, the 47 villages on Sagar Island (which constitutes a block) are covered by 9 Gram Panchayats.

5.2.2. The selected islands and villages, energy needs and energy use

From the installation of the first solar mini-grid in Kamalpur village on Sagar Island in 1996, WBREDA implemented the 17 solar mini-grid and solar hybrid mini-grid projects on seven islands up to 2012 in the Indian part of the Sunderban Islands. Twelve of these power plants

[24] The houses are constructed in a way that makes them optimal for temperature regulation. The thatched roofs touch the ground so that less heat enter the huts, and the walls are made thick with sediments and thereby keep the interiors of the houses cool.
[25] Statistical Handbook West Bengal 2011, Bureau of Applied Economics and Statistics, Government of West Bengal

were located on the two islands selected for this study, Moushuni Island (2 power plants) and Sagar Island (10 power plants).

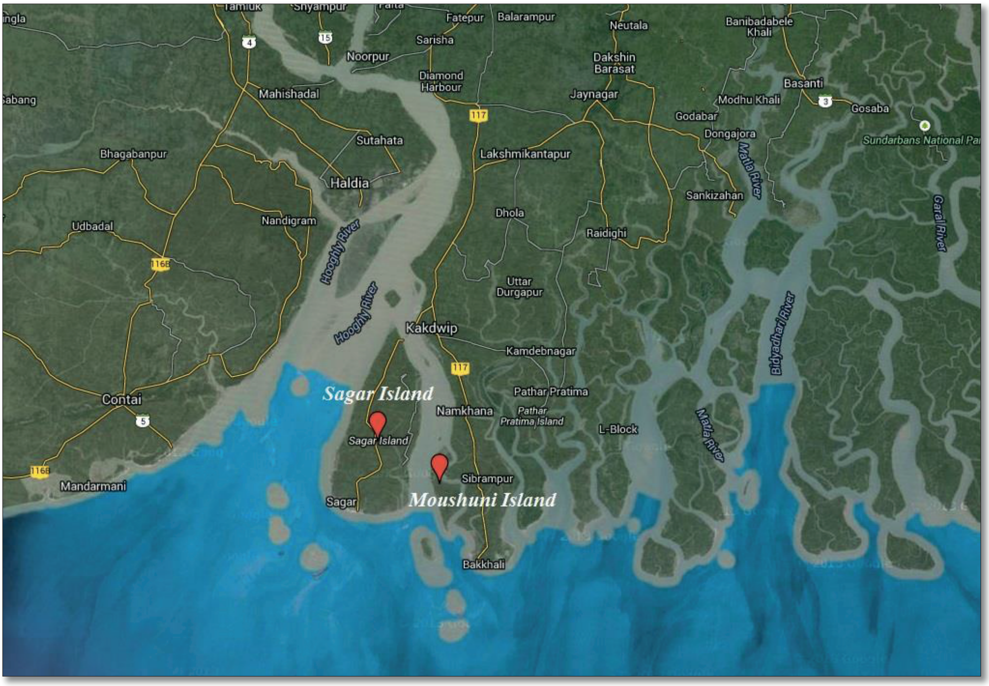

Figure 8. Sagar and Moushuni Islands in the Indian part of the Sunderban Islands. Source: Google maps.

Sagar Island is a larger island than Moushuni (which has only 3 villages), and is less remote. Sagar Island has a population of about 200,000 (Shrank 2008), and Moushuni Island has a population of about 24,000. Sagar appeared to have more wealth than the other islands in the area and had a paved main road and a public transport system. On Moushuni, the common modes of transport were walking by foot, bicycle and rickshaw and the markets were fewer and smaller than on Sagar Island. The six villages selected for this research were Bagdanga and Baliara on Moushuni Island and Kayalapara, Khashmahal, Natendrapur and Mrityunjoynagar on Sagar Island. These varied in time since power plant implementation, size and location on the island. The power plants in these villages were installed between 1996 and 2005, and the number of customers for the power supply in each village varied between 70 and 300, according to WBREDA's records of payment.

The main energy carriers used in the Sunderban before and along with the use of the solar power supply were kerosene for lighting, and firewood, cow dung and rice husk for cooking purposes. Torches and candles were also used. A few diesel generators were used in Sagar Island mainly serving a few businesses along the main road of the island.

5.3. The energy system design and the underlying considerations

This section explains the shaping of the socio-technical designs for the solar mini-grids and how they were intended to function (dimension C of the framework of analysis). Factors that influenced the socio-technical design included the visions, skills and considerations of the project implementers, the contributions of ideas, knowledge and opportunities by other actors, the national and international framework conditions, and the local, socio-cultural context.

5.3.1. The role of the project owner and the visions behind the solar power supply systems

The initiator and owner of the local energy systems studied in the Sunderban Islands, the state agency WBREDA introduced above, worked on development of renewable energy supply in the state of West-Bengal by assisting the State Government, local village bodies, municipality bodies and NGOs on different matters related to renewable energy supply. Their first director, Mr. Gon Choudhuri, was the initiator and leader from the start in 1993, and WBREDA was the first state agency of its kind in India. The same person was the driving force for the solar mini-grid systems in the Sunderban Islands studied here, until he left the position in 2008. Colleagues were also strongly involved from the start, and continued up to the time of fieldwork in 2010.

A central motivation behind the implementer's initiative in the Sunderban was to provide lighting for homes, small businesses, market places and streets to improve people's quality of life, protect them against snakebites and enable business activities, handicraft and other types of activities in the evening. The former director described the starting point for the development of the Sunderban solar mini-grid model:

> In 1996, you know, there was not a single light in Sunderbans, no light, all kerosene oriented. So when we went to Sunderbans, people they were telling us that 'can you replace this kerosene lantern? We need the light (Interview: Gon Choudhuri, 2010).

Affordable access to electricity for people with limited material resources was an important part of the vision. Electricity was perceived as a means to combat poverty and to promote development. Moreover, Mr. Choudhuri had a passion for renewable energy, especially solar energy. There were also not many other options available. Extension of the national electricity grid to the Sunderban Islands was not realistic at that time, and is still not so for most of the islands. Diesel generators were already in place in a few locations, but this was an expensive and impractical option due to the difficult transport route for the fuel.

His vision also included the idea of creating solar mini-grid systems as an alternative to smaller solar systems on individual buildings, because these village level systems were expected to have several advantages over individual systems. Solar mini-grids could deliver better quality power, alternating current power that could be used for operating small electrical machinery for village industries, and it could be possible to get payment from users for the power consumed (Chaudhuri 2007). The following sections show how WBREDA, with Mr. Choudhury as a champion, designed their solar mini-grid model, through a range of detailed considerations on how to ensure smooth functioning, local ownership, effective collection of revenue and several other characteristics.

5.3.2. The electricity services provided

The project implementer found it possible to supply electricity for light fans, black and white TVs and a few other applications. Light, which was viewed as most important, could be provided for some hours every evening, five to six hours with optimal functioning of the power plants, starting from 6 hours pm WBREDA chose to have two main options for the households, businesses, offices or others who decided to subscribe to the power supply. They could have either three or five electricity points in the house, drawing different electricity loads[26] from the power plants, and pay different tariffs. The three points' connection could be used for three lights, or in some cases for one or two lights and a table fan or a black and white TV.[27] Mobile phone charging was also introduced in some of the villages in later years of these projects. The five point connection enabled installation of three light points as well as sockets for a table fan and a black and white TV.[28] Other types of connections were also provided, as for example in Kaylapara village, for special types of customers. These customers included a video hall, a school and a public office.[29] The power supply was not meant for appliances that would require more electricity to run, such as large rice mills, big water pumps, husking machines, welding machines or electric stoves.

5.3.3. The technical design

The project implementer put much effort into developing the technical design for the solar mini-grids, in close cooperation with the companies that supplied equipment. One challenge was to adapt it to the salty, stormy conditions in the Sunderban Islands, and the first inverter became damaged by salt. The solar arrays varied in peak capacity between 25 and 110 kW, and each battery bank with batteries of the lead-acid type had an appropriate size for the solar arrays and the planned hours of supply. Depending on use characteristics and maintenance quality, the capacity of the batteries would diminish over their lifespan of 4-6 years, depending on usage pattern, until a new battery bank would be put in place. Inverters were installed for inverting the power from direct current (DC) generated from the solar panels, to alternating current (AC) delivered to the customers.

A feature of the local context, the dense settlement pattern, made it possible to connect many people although the spatial outreach of the mini-grids was limited. The radius

[26] Electricity load means the amount of electricity drawn by a specific type of electricity consuming device. The load is measured in Watts (W). For example, a hot plate on an electric cooking stove typically draws around 500-2000 W.
[27] The planned electricity load per customer for the three points connection was maximum 60 W in the initial phase of the projects, and up to 100 W in some of the later power plants.
[28] The planned load for the five points connection was maximum 120 W in the initial phase of the projects, and in later power plants 150 W.
[29] They drew from 75 to 300 W.

of the electricity grid measured from the power plant to the end of each branch of the line in most cases was around two km, because a longer line would lead to a drop in voltage for customers at the outer parts of the lines, reducing the quality of the light or other services.[30] The electricity lines were single phase or three phase, low voltage distribution lines (240/400 Volt, depending on single or three phase), complying with the standard of conventional distribution grids in India.

It was important to dimension the power plants to suit with demand for electricity as will become clear below. The project implementers estimated the likely demand in the various villages, in terms of number of customers. They held information meetings and did surveys as part of their planning, and sometimes made lists of interested customers before deciding the dimensions of the systems. They followed standard governmental tender procedures, and purchased different kinds of equipment from different suppliers. Technical equipment was transported by boat, and people carried large and heavy batteries and solar panels ashore on the islands and sometimes transported them by bicycle vans for several kilometers. Although challenging, a key WBREDA official pointed out that this was one of the easier tasks in the project. Suppliers carried out the installation work under supervision from WBREDA, and local people contributed with manual work.

5.3.4. Financing of the technical equipment for the solar mini-grids

The project implementer managed to mobilize financing of the investment in technical equipment through grants from the MNRE and the West Bengal state government[31] and a few other sources. Loans were sometimes taken from IREDA financed under a World Bank line of credit. Due to the long-standing work on solar PV in MNRE at the national level in India, the technology was already familiar to ministry officials. The new ideas from Mr. Choudhuri in the 1990s were a next innovative and promising step, making solar PV provision into something larger than the solar home systems. There were only small variations in the financing sources used by WBREDA over the years. The funding from the state level was an important addition to the funding from the central government. The local Gram Panchayats provided land for the power plants through a leasing arrangement at low cost and in some cases land was also donated by individuals or by the village community.

Based on examples from 2001-2004, the total cost for each power plant (25 to 110 kW installed capacity) was from approximately 6.6 to 29 million Indian Rupees (115,000 to 510,000 Euro).[32] The local grid itself would range from approximately 0.9 to 1.25 million Rupees (15,700 to 22,000 Euro).[33] This included the solar PV modules, foundation, module mounting structure, charge controllers, inverters, batteries, cables, wires, junction boxes, installation, commissioning and freight. The cost of the power plant building came in

[30] The possible outreach of such power lines varies a little bit with the density of the connected households.
[31] Department of Science and Technology and Non-conventional Energy Sources, Government of West Bengal.
[32] The cost per kW installed capacity was around 265.000 Indian Rupees (approximately 3450 Euro).
[33] The cost per km of line varied between 180.000 Rupees (2349 Eur) and 250.000 Rs (3263 Eur) in the Sunderban, for single phase lines. The total length of the lines in each mini-grid was up to around 5 km.

addition. The costs for such power plants have gone down considerably since that time because of dropping prices of solar PV panels in the global market.

5.3.5. Local involvement, organizational arrangement

Participation at the local level, especially among village leaders was considered important by WBREDA to ensure support for the projects. They saw village politics as an important factor to take into account. Support from the local leaders could facilitate the implementation process and set up of the local organizational arrangement. Mr. Choudhuri explained that he, as a leader of WBREDA, met with the leaders in the villages, and informed them about the kinds of problems they would have to help him to solve in order to make the power supply possible. For instance they could help raising awareness and interest and thus a good customer base.

The initiative to build a power plant in a village sometimes came from WBREDA, especially for the first power plants, but also sometimes from village representatives who had seen the power plants in other villages. In Khashmahal village on Sagar Island, for instance, the initiative for building the power plant had been taken by a political leader in the Gram Panchhayat.

WBREDA initiated local organizational structures to oversee the electricity provision in the villages. For the power plants on Sagar Island, the Sagardweep Rural Energy Development Cooperative Society was created in order to have the overall management responsibility for all the power plants on the island. On Moushuni Island, the power plants were managed by the Gram Panchayat. Local committees were initiated by WBREDA in the villages they worked with. In Sagar Island each of the villages had such a committee, while in Moushuni Island a similar committee covered the solar mini-grids in two different villages. The responsibility of the committees (called beneficiary committees or village energy committees) was to recruit customers in the beginning, to control that the customers followed the rules for use of electricity and to address problems related to the payment for the electricity. After warnings had been given without effect, they could decide to disconnect a customer. The committees would at the same time represent the community members or customers and speak for them, for example regarding the tariff level. In these ways, the committees would support the co-operative (in the case of Sagar Island), or the Gram Panchayat (in the case of Moushuni island) to ensure smooth functioning of the local infrastructures.

5.3.6. Economic design

WBREDA found it important to have a system where people paid for the electricity services, but with low prices to ensure affordability. The power supply systems were planned to provide sufficient revenue for covering the costs of operation and maintenance of the systems, including purchase of new batteries when needed. It was also seen as realistic to get a surplus after the expenses of operation and maintenance had been covered and thereby achieve some cost recovery of investment costs. The revenue would depend on the tariff level, the number of customers of each power plant and the compliance of these customers to make their required payment. The main expenses would consist of payments to operators and contractors, including battery replacement, which was likely to be the largest cost.

The tariff level was decided through mutual consideration between the project implementer and the local committees. At the start-up time the tariffs varied a little bit from plant to plant in the six villages visited, indicating the influence of local decision making. According to Mr. Choudhuri, he listened to the people he met in the villages when they told him that "we are poor people", and took this into account during considerations on tariff levels.

Those people who decided to subscribe to the power supply would pay a connection fee and thereafter a monthly tariff. For the three points' connection, the connection fee was 1000 Indian rupees (15.8 Euro) at the time of the fieldwork. For the five points connection, the fee was 1500 Rupees (23.5 Euro).[34] The monthly tariffs for the electricity use in most of the power plants on Sagar Island were 80 Rupees (1.7 Euro) and 135 Rupees (2.9 Euro) respectively, at the time of the fieldwork. In Moshuni Island the tariffs were 75 Rupees for three and 150 Rupees for five points.[35] These amounts were fixed monthly fees independent of consumption, and there was no metering of the electricity consumption of the customers. The reasons for not installing meters were that the power was going to be distributed in equitable ways (limited supply for fixed hours of supply), that the costs of installing meters were high, and that technical difficulties occurred when metering was tried out. The consumption of electricity within the hours of supply was determined by the kinds of appliances that were used. The users of the electricity here found a space for stretching the limits for this electricity access without paying more, as explained below.

5.3.7. The arrangement for well-functioning daily operation and management

The first solar mini-grid, implemented in Kamalpur village on Sagar Island, was operated and maintained by an engineer from WBREDA who stayed in the village. After a while, when the number of projects grew, it became necessary to find other ways to ensure smooth operation and maintenance of all the plants. WBREDA therefore developed a contract system for operation, maintenance and repair, so that contractor companies would be responsible for providing skilled operators. The contractors were selected through open tendering processes. These contractors, in cooperation with WBREDA, selected operators for the daily supply of electricity. There were mostly one or two operators at each power plant. Their tasks included turning on and off the power supply every day, keeping records and doing general operation and maintenance of the technical equipment. They were also responsible for monitoring the charging and discharging of the batteries and making decisions of when to cut the power supply each night. The basic maintenance was also their responsibility, including the cleaning

[34] In the initial phase, for the earliest power plants, the connection fees had been lower – 500 and 1000 INR respectively, for the two connections.

[35] This had remained approximately the same since the two plants in Moushuni opened in 2001 (Bagdanga village) and 2003 (Baliara village).

of PV modules/panels, checking the level of distilled water in each battery and re-fill it, and applying vaseline to prevent corrosion of the battery terminals.[36]

One type of contract covered the operation and daily maintenance, while another type covered the responsibility for annual maintenance.[37] The operation contracts were often signed with local entrepreneurs who used their own service personnel. They hired operators, decided their salary level and paid them. The annual maintenance contract was often combined with the installation of the power plant. The installer would thereby have to provide qualified staff for operation of the power plant for a minimum number of years (TERI 2009). Local people (men) who demonstrated technical skills were sometimes selected and trained during the installation phase. If there was a problem in the electronic devices, the contractors for operation would report to WBREDA, who would contact the contractor responsible for the annual maintenance.[38] The follow up and support for local operators was to be done by the contractors.

The procedures related to the users of electricity mainly consisted of collection of payment, controlling the amounts of electricity they used, and dealing with their complaints. Tariff collectors were responsible for collecting payment once per month. Issues of failure to pay, over-use of electricity and complaints were the responsibility of the local committees.

5.4. Actual functioning of the system

The section above concerned the way in which the solar mini-grids were intended to function. This section is guided by questions about how the energy systems actually came to work in practice, how they changed over time, and why (dimension D). This dimension is crucial because it concerns the factors that shape the actual outcomes of the actors' efforts, which are always different than intended.

This dimension is analyzed along five main themes. The first theme is about the mutual influence between people's practices and the functioning of the energy system. The second theme is about the dynamics between the technical and social elements of the system. The third theme is about how the daily operation and organizational set-up functions and why, and the fourth is about the economic performance and its reasons. The fifth and last theme is about the role of changing framework conditions on the system's functioning. Within each of these themes, the actual functioning is identified and its reasons discussed.

Social learning processes in relation to the implementation and use of technology are generated through the dynamic interaction between technology and its users, and between technical and societal elements of the local socio-technical systems. Learning is particularly intense for those people who have taken on the largest responsibility for the outcomes, i.e. actors who initiate and carry out socio-technical experimentation, but also other involved

---

[36] Maintenance of the distribution lines was taken care of either by the operators or line men.

[37] In the Annual Maintenance contract, there were two types of services. One was "breakdown maintenance" and the other was "preventive maintenance". The first was related to breakdown in the power supply and the other was related to regular maintenance once or twice per month. The payment under the contract was fixed.

[38] A third type of contract was signed for maintenance of the local electricity grids in case of lines breaking due to storms or clearing trees. Local entrepreneurs usually got these contracts, to facilitate quick and reliable services (TERI 2009).

actors learn underway. The representatives of the project implementer WBREDA, in this case, tried out solutions in villages, monitored the way they worked, learned, innovated, and made improvements underway based on changing contextual factors both at the local level and higher geographical levels. There was a process of experiencing, learning and changing practices also for the users of the electricity, as explained below.

The purpose of this analysis is not to evaluate or measure the degree of success of the power supply but to achieve knowledge and understanding of factors that influenced the functioning of the power supply systems. At the same time, since emphasis is put on understanding why the system functioned the way it did, it is still necessary to look at which factors led to achievements and which factors led to problems. This is discussed in light of the quality criteria or objectives that WBREDA strived towards such as affordability, economic sustainability, and smooth operational functioning. Affordability, as well as other qualities of the electricity services, are discussed under the section on electricity access (dimension E), while other qualities of the system are discussed here.

5.4.1. The mutual influence between people's practices and the functioning of the system

As mentioned in Chapter 2, there is a dynamic interaction between users of a technology and technical devices. Only through practical engagement with the technology one can get to know how it can be used and under which conditions (Ornetzeder and Rohracher 2005). Technology is often gradually appropriated by users and become part of their everyday routines or practices (Sørensen 2013). The users of a technology can be different kinds of actors. The concept of users is here used about the customers of the mini-grids and others who used the electricity services provided, although the local operators are also users of the technology.

During fieldwork it became clear that people's use of the electricity services in the Sunderban had changed immensely over time. This had influenced the functioning of the power supply which again influenced the ways in which the people could make use of the electricity. In the first power plant, the initial demand for the power had been so low that the first battery bank had got damaged because of this. At that time, electricity was something completely new to the people. An important concern for WBREDA when implementing the following solar mini-grids was to spread awareness in the communities to get many subscribers.

At the time of the fieldwork demand had surpassed supply and there were long waiting lists. For instance, in Kaylapara village, there were 250 customers in February 2010 according to the operator, 225 households on waiting list, and the total number of households in the village was 691.[39] In each of the villages visited, and in all the other mini-grid villages, according to WBREDA officials, the demand for the electricity supply had become very high.

[39] WBREDA's records from 2009 said 187 customers at Kaylapara village.

The demand for electricity had grown in two ways, firstly, through the increasing number of customers until the capacity of the power plants were saturated, and secondly, through increased use of electricity by each customer. Since electricity consumption was to be administered without metering, it was relatively easy for customers to change practices and start drawing a little bit of extra electricity in their shops and homes when they got used to electric appliances. For example, they learned they could use stronger light bulbs to get brighter light, while still paying the flat rate per month. Other ways of using electricity emerged than those the solar mini-grids were planned for, such as charging of batteries or other devices for people who had not got a connection. Other examples were photocopying machines and small grinders (0.5 or 1 HP). Some people had also made a so-called by-pass, stretching a line over to their neighbor who didn't have connection, and other informal/unauthorised connections were also prevalent in many villages – an unruly kind of "users' innovation". WBREDA was unable to remove such unauthorised connections and this also created undue pressure on the power plant batteries.

The trust based system with control of fellow community members by the local committees had worked well before. As mentioned by Mr. Choudhuri, due to the participation of the local people, the revenue collection had been exceptionally high. This was also found in previous studies (Chakrabarti and Chakrabarti 2002, Gulati and Rao 2007, Shrank 2008). However, at the time of the fieldwork it seemed like the practices of over-use of electricity had become well-established and socially accepted and silently approved by local committees and operators. This was observed by the many strong light bulbs used in the market areas (CFL lights of 36 W instead of the allowed 7 W lights). The Beneficiary Committees had carried out control earlier, and also imposed penalties, but the task of looking after the practices of hundreds of co-villagers and change these practices was probably a practically and socially difficult task. The increased use of electricity influenced the battery banks of the power plants, which in turn reduced users' satisfaction.

After seeing this trend of strong growth in interest and capacity problems in their first projects, WBREDA started to build larger solar power plants. Up to year 2000 they had built plants with a capacity of 25-26 kWp, and thereafter the new plants got a capacity of up to 110 kWp. In some places they installed additional generation units such as small wind-generators and biomass gasifiers. Mostly, the implementing agency chose not to expand the already installed power plants. There was no mechanism for expansion built into their strategy, and they had very little resources for upgrading of existing plants. The focus was on reaching more and more villages. It was a constant struggle to secure funding for each power plant, and funding for expansion of existing plants was not at hand.

5.4.2. The interaction between the technical and social elements of the system

There was a strong mutual influence between battery characteristics and the way different actors related to the mini-grid systems. The battery banks had created challenges for almost all involved people, at the same time as the practices of the customers, operators and other people contributed to the battery problems. The degradation of the batteries in the villages visited had tended to go faster in later years than earlier.

The reason for the battery problems was likely to be a combination of the normal degradation of the batteries, the way they were used, and varying quality of batteries from battery producers. The way the batteries were used was in turn influenced by the social organization, operation and management of the power supply. The over-use of electricity by the customers influenced the speed of the discharging of the batteries, which is a factor that stresses the battery and shortens its life.[40] Controlling the speed of discharge is equivalent to controlling the load – i.e. the way in which the customers use the power. This could be difficult, and gave social challenges in terms of necessitating non-technical measures to deal with the technical shortcomings of the batteries.

The actions of the operators influenced the batteries by the number of hours they allowed the power to be used. The operators were supposed to switch off the power supply when the discharging of the battery came down to a certain level, as deep discharging harmed the batteries. However, there was a social pressure from the customers to get power for as many hours as possible in the evening. If the operators adjusted to this pressure and thereby kept the power on for longer time than what was recommended for the batteries, they contributed to further degradation and shortening of supply. A feature of the geographical context that affected the battery problems was the long and cloudy monsoon season (around 4 months). The charging was less than usual during this season, and the batteries sometimes became permanently damaged if they were not handled carefully by the operators. A central WBREDA official described the responsibility of the operators in the following way:

> Mostly, people do not bother about the problems in the power plants. There is a mental pressure on the operator, so he has to tackle the local situation, even social problems. He is the key person and should take the decision on how to operate the power plant on the basis of battery state of charge, load demand, etc. He has to take care about the battery by not discharging batteries beyond its limits, which may cause permanent damage of batteries (Interview: WBREDA official, 2010).

However, the same representative also said that some of the operators lacked the skills, experience and willingness to abide the instructions and guidelines. During fieldwork it was observed that maintenance by the operators varied between power plants, for instance the filling of distilled water into the batteries. A problem for the operators was sometimes lack of distilled water.

Even if handled in perfect ways, the batteries would still need relatively frequent replacement.[41] According to a project engineer at WBREDA, a way to reduce the recurrent battery problems, which also involved the problem of defining responsibilities at various levels, would be to let the contractor who is responsible for the charging controller cover responsibility for batteries from supply to operation, and in case of too early failure, also replacement. This solution would thus put one single juridical body in charge of operating the

[40] Batteries have a recommended rate of discharge specified by the manufacturer.

[41] In addition to the battery problems, some other technical problems were also reported in the power plants, mainly in the inverters and charging regulators.

batteries in a technically sound way. They also wrote comprehensive maintenance contracts for 5 years instead of annual maintenance contracts in order to bind the contractor for better operation and maintenance.

5.4.3. The functioning of the daily operation and organizational set-up

WBREDA tried out a comprehensive framework where several other actors were involved. The emerging practices of the involved people strongly shaped the way the systems worked, as explained above, which was of course not possible for WBREDA to control, nor to anticipate. In response to the emerging practices of these other actors, WBREDA adjusted their own strategies and roles and tried to change the contracts, the technical design and other elements they could have some control of. They also had to adjust to or merely accept to elements outside their control.

The following two figures show the roles of the involved actors of the solar mini-grid system in each village in Sagar Island – first the roles they were intended to have, thereafter the roles they actually played after some years of opeartion. The first figure illustrates the planned institutional organisation of the operation and customer management for Sagar Island, as explained earlier in the chapter. The cooperative and the contractors were intended to play important roles for the management, operation and maintenance of the power supply systems in order to enable replication of the power plants by delegating WBREDA's responsibility. Important lines of communication and interaction would go between the operators of the power plants and the contractors and between the customers, beneficiary committees and the cooperative. The contact between the cooperative and WBREDA would be about the management and use of the revenue, hiring of contractors and battery replacement.

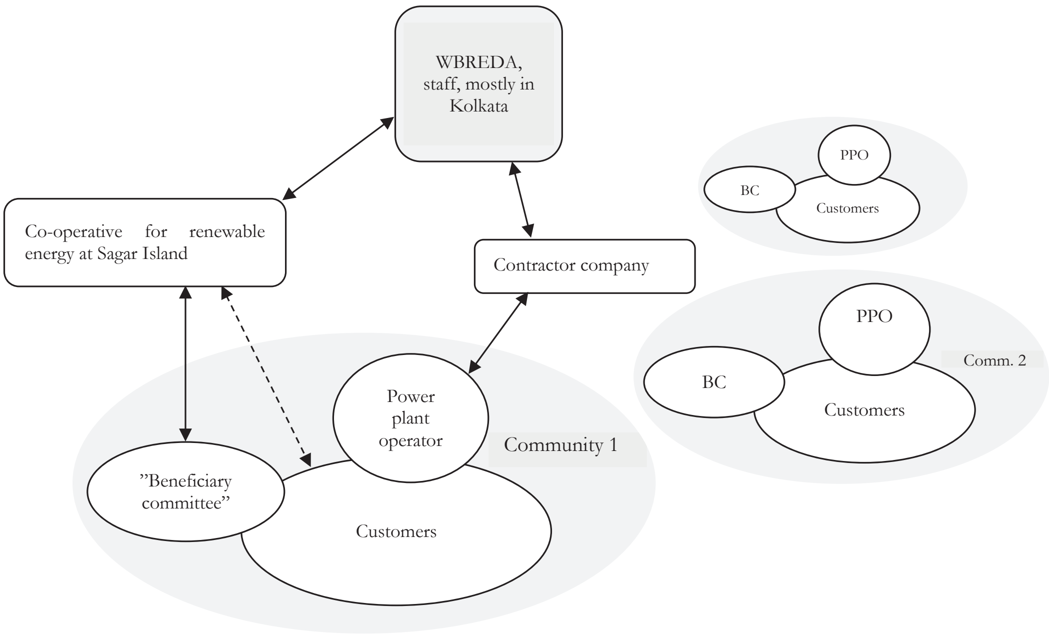

Figure 9. The planned institutional organization of the operation and customer management for each solar mini-grid system in Sagar Island.

The next figure shows the practiced institutional organisation on the same island. WBREDA became more involved in the details of operation and maintenance than they had planned to be, and the contractor companies and the cooperative played weaker roles than what was hoped for by WBREDA. This is indicated by the dotted lines.

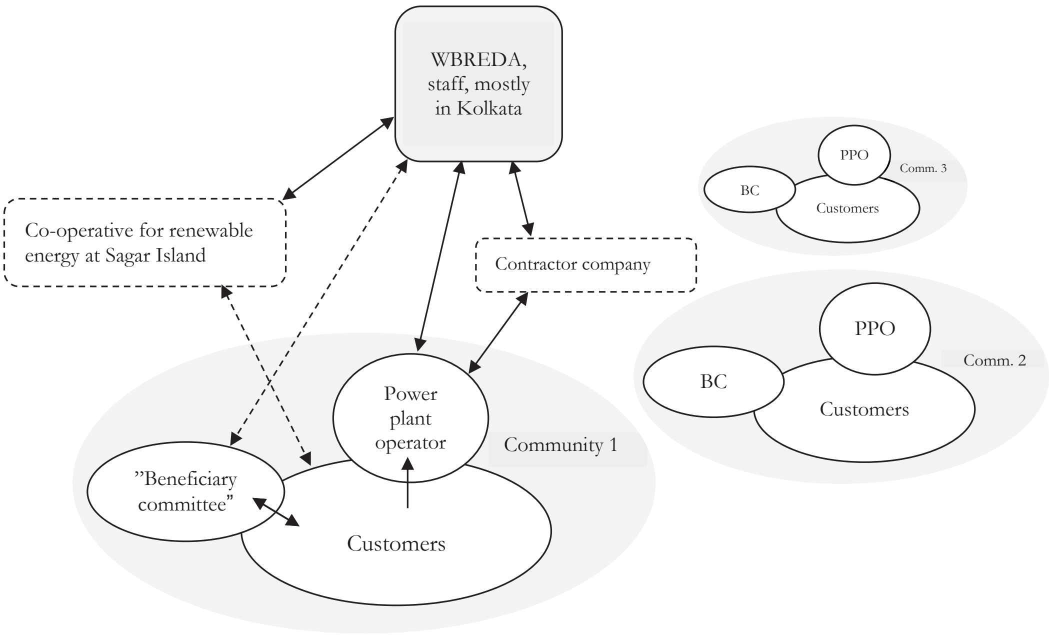

Figure 10. Outline of the practiced, institutional and operational organization for each solar mini-grid in Sagar Island, based on figure published in Ulsrud et al. (2011).

The figure further shows that WBREDA was contacted by the other actors when major problems occurred, and the replacement of batteries and other major improvements depended on them. The role of the co-operative became to collect the electricity tariffs in the villages at Sagar Island and take care of consumers' grievance redressal instead of also playing a stronger role in the management and operation of the solar mini-grids, as mentioned in Ulsrud et al. (2011). The arrow between the power plant operator and the WBREDA box illustrates phone calls from the operators to WBREDA to talk about problems or discuss decisions to make during the operation of the power plant. It was common for the operators to call WBREDA directly instead of calling the contracting company that had hired them. The same kind of communication sometimes took place between the local committee members and WBREDA. Moreover, WBREDA stayed in touch with contractors. The arrow from the customers' box to the operator means that the operators felt a pressure from the customers to stretch the limits of the solar power supply. This comprehensive role for WBREDA was time consuming, since they dealt with 17 such units. This demonstrates that the project implementer's attempt to delegate and outsource responsibility was a difficult undertaking, especially because it was difficult to ensure committed work by different involved actors. WBREDA tried to develop incentives and agreements, within the constraints of economy and available control mechanisms.

Although several individual and collective actors had played important roles for how the power plants came to work in practice, the operators of the plants appeared to be key actors for the functioning of the power supply systems, as indicated in the previous section.

They were not supposed to deal with the customers directly, but since they had an important impact on the quality of the services for the users, they had to deal with the expectations and complaints from them.

Some of the operators seemed to lack motivation for their tasks, and the salary level (down to 2000 Rupees (31 Euros per month) was expressed as one of the reasons. Some of them said that they were looking for other jobs. According to the operators there were few visits for follow-up by WBREDA at the time of the interviews, fewer than before. There were also some problems of salary payment from contractors to operators. The operators made phone calls to WBREDA when the contractors had not paid. A factor that might have further reduced the motivation of the operators was also that the functioning of the power plants would gradually go downwards even if they did their best.

The operators did have a few advantages though. They got rooms at the power plant buildings, had access to electricity for 24 hours per day, and could offer their friends some services (observed in power plants at different times of the day and night). Visitors watched TV with the operator, long after villagers had gotten their power switched off. Visitors also charged their phones or took a shower. The power plants also had fans, toilets and light. The operator in one of the power plants (Bagdanga) used a solar powered water pump to irrigate a field of potatoes, vegetables and flowers around the power plant. These observations showed creativity and entrepreneurial tendencies, but the operators still had few opportunities for own initiatives in relation to the power plants.

Both a key WBREDA official and power plant operators expressed dissatisfaction about some of the contractors, who could potentially have played an important role in ensuring good functioning of the power supply. For example, the contractors sometimes failed to give sufficient training to the personnel they hired for the power plants. The operators also sometimes mentioned the contractors in order to explain the lack of action on various issues. WBREDA held some workshops to strengthen the capability of the operators to take care of as many tasks as possible, including repair that the contractors had been supposed to do, small problems that would shut down the entire power plant. It often took time before the contractors would be able to send their technicians.

5.4.4. The economic performance and its reasons

WBREDA openly explained the challenges of economic sustainability to the research team. During the first years, while the payment discipline of the customers had been good, the revenue provided some of the funds for operation and maintenance, but it is unclear how much, and the contribution probably varied from village to village. An example is provided by Shrank (2008) who found that the yearly revenue of Mritunjoynagar power plant was about half of the annual expenses when battery replacement was included. The revenue has later been reduced, most likely. The description of the economic performance in this analysis is based on information given by WBREDA staff and other involved actors, as well as data on current levels of income and expenses. The reasons for reduced payment discipline stated by the community members were especially the shortened hours of supply because of the need for battery replacement and people's interest to get 24 hours electricity supply. It may also have become a habit not to pay, and some local political issues were reported to play a role in some of the villages. WBREDA's expenses may also have become higher than expected. For instance, battery replacements were expected to be needed every 7th year, but the actual time span was 2-3 years less than that. A further problem for WBREDA was that it was costly to use good contractors that provided skilled staff.

Shrank (2008) has argued that the community management model of the solar mini-grids did not provide the right incentives for the local actors to ensure economic sustainability. For instance, it might be a problem to increase tariffs for fellow community members in order to reflect the actual costs of operation and maintenance. He also argued that locals may not have the business competence to set profit-maximizing tariffs. A factor that reduced the incentives of the local actors was also that they did not have direct financial stake in the project, he argued.

WBREDA actually tried out a model for encouraging entrepreneurship, a franchise model, during later years, influenced by parts of the Decentralized, Distributed Generation (DDG) scheme. They tried to auction off the operation and maintenance of some plants in order to get an entrepreneur. Community organizations could take on the job. The franchisees would for example procure electricity in bulk from the power plant, distribute to the consumers and collect revenue from them and keep the surplus. Much optimism and hope was attributed to this model, but the experiences were not positive. According to a person who was involved in working out the model, as an advisor, it never took off, because private developers were not willing to guarantee that the power plant would be rectified within 72 hours of complaint, as was set as a condition. Most of the DDG projects in India appeared to be implemented by state agencies.

5.4.5. The role of changing framework conditions for the system's functioning

In addition to adjusting to the practical experiences in the villages, WBREDA also adjusted their strategy for off-grid power supply in the Sunderban region due to changes in the policy framework of the central government in India. The Remote Village Electrification (RVE) program stimulated the complementary installation of subsidized solar home systems and also small power plants at schools and other public institutions, in addition to facilitating some of the later power plants.

The grid extension under the national rural electrification programme by the State of West Bengal played a strong role for the plans ahead because the grid was on the way to Sagar Island at the time of the fieldwork. A likely reason was that the solar mini-grids had worked as a kind of "pre-electrification", which had prepared the market for electricity through building up demand in the villages. WBREDA expected the gridlines to reach Sagar in 2012, but not yet the remote villages. The planned grid extension created uncertainty – should the mini-grids continue to be kept operating and undergo battery replacements or would this be a waste of funds, relevant only for a short period?

5.5. Resulting access to electricity services for different groups

How did WBREDA's Sunderban model work in terms of providing access to useful electricity services for various groups? Whether community members could get a connection to the grid was especially influenced by geographical distance from the power plants, the routes for the power lines, the tariff levels, the households' and other customers' economy, the capacity of the power plants, and the availability of alternative solutions.

5.5.1. The role of geographical distance to the power supply

The geographical location of the community members in relation to the power plants was an important condition for their possibility to get a connection to a solar power plant or not, not only depending on the distance from the power plant, but also on the street or road. Only in rare cases the lines were extended after the start-up phase, but this would still be within the technical limits of around 2 km's distance from the power plant. Many households and other potential customers were therefore not within reach.

The initial decisions on where to locate the power plants had been made by the Gram Panchayats (the lowest political unit for decision making in villages), based on discussions with WBREDA. The final decision had often been made on the basis of reasons presented by WBREDA, such as the need for placing the power plant centrally in the villages, for technical and economic reasons. WBREDA tried to avoid agricultural land and sites with many trees, in order to avoid conflicts.

A few of the electricity services reached beyond the geographical limits for the mini-grids. These services included mobile phone charging (sometimes provided through small, privately owned diesel generators). There was also lighting at schools, and these gradually got their own power plants installed by WBREDA. Light in the market areas at night and street lights also benefitted the community as a whole. Increased economic activity in the village market reported by various informants could also give extended effects.

5.5.2. Affordability

Affordability of the electricity services varied between the community members because of the differences in their economic situation. The tariff was affordable and even cheap for most of those who were connected to the mini-grids at the time of the fieldwork. The tariffs had been kept relatively stable over the years, while the general price level for other goods and services had increased, thereby decreasing the tariff in relative terms. However, the survey data collected on energy expenditures and income level for those who were not connected showed that the connection fee constituted a barrier to getting connected for the poorest families (Winther 2014).

Most of the customers chose the cheapest option for connection to the solar mini-grids – the three points' connection. In Khashmahal, for instance, 108 customers had chosen three points and 21 had chosen five points. In Kayalapara the ratio was 157 to 30. In Mrityunjoynagar it was different – only 45 customers only had 3 points while as many as 65 had five points. This village looked like it had a larger number of relatively wealthy households than the other villages visited, based on the sizes of the houses.[42] For most of the businesses, the electricity was probably cheap. WBREDA officials expressed frustration about the provision of cheap (subsidized) power to businesses. Higher revenue from them could have improved the economic performance of the solar mini-grids.

Economic sustainability had become difficult, but affordable services for many people had been achieved, although not for all. The case study did not give certain findings on the portion of each community reached in each of the six villages, but the available information about number of households and number of connections indicate that 30-50% were connected, and that many households had informal connections and were served by battery charging done by those connected. There was a dilemma between the objectives of economic sustainability and affordability, and the attempts to fulfill both led to partial fulfillment of each, while prioritization of one might have hampered the other.

5.5.3. Quality of the electricity services and users' satisfaction

The main problem of quality of the electricity services was the gradually shortened hours of supply over the lifetime of the batteries in the power plants. Apart from this problem the reliability of the electricity supply seemed to have been good most of the time. Technical problems the local operators could not solve on their own, would be solved by technicians sent by WBREDA or the contractors. Sometimes it took time for them to come to the islands, and the power supply did sometimes not work for a period.

The customers had grown less satisfied over time. One reason was the tendency of reduced quality of the services, which they had contributed to by the over-use of electricity, though not intentionally. Another reason was changed expectations to what electricity can do for them. People had been excited when light was switched on for the first time in their houses. They had appreciated the opportunity to have light for a few hours per day. At the time of the fieldwork, customers expressed the need to have electricity supply for 24 hours per day for 7 days per week. They knew there were plans to include Sagar Islands in West Bengal's main grid.

This research is not going into socio-economic impacts of the electricity services. The focus here is on the challenges of making power supply available. However, by using and expressing demand for the electricity services, the users showed that the electric supply was important for them, and that they prioritized it enough to be willing to spend their limited economic resources on it.

[42] The numbers of connections in the different villages are according to WBREDA's record of payments as per October 2009.

5.5.4. Availability of alternative solutions

If somebody found that they could afford the use of electricity from the mini-grid after the main subscription phase, the capacity of the power plant could already be fully utilized. They could sign up on a waiting list, but there was little chance to get a connection.

Over time, the solar PV technology became familiar to people on the islands because of the solar mini-grids. Those people who could afford it (relatively well-off households) started to purchase their own solar home systems. These could provide similar electricity services, especially for meeting lighting needs. A few customers of the power plants also purchased solar home systems and used them as a complement. WBREDA started to provide support for solar home systems for people without a connection.

The timing for use of electricity was more flexible with a solar home system, TV could be watched during the day and light could be switched on if need arose later in the night than with the mini-grids.[43] The light provided by the mini-grids suddenly went off when the power plant was switched off, and the time for this varied a little bit from day to day. This was inconvenient for the customers (as vividly described by a woman who experienced this while cooking in the evening).[44] Other alternative solutions in some villages were a few solar charging stations installed by NGOs, and small diesel generators used by various businesses and farmers.

5.6. Replication and diffusion of learning

"Diffusion of learning" from the socio-technical experiments, as formulated by Brown and Vergragt (2008) was not an explicit topic for this research on WBREDA's solar mini-grids in the Sunderban Islands. This aspect of the Sunderban project, and "replication" of the energy model, was studied only as far as it concerned the project implementers' own gradual implementation of new and improved versions of their model in more villages and islands. The topic of replication was later made more explicit in the framework of analysis (as dimension F), not meant as direct copying, but building on or using elements of a pilot or demonstration project.

Two kinds of outward learning and replication are relevant to look at, as mentioned in Chapter 3; the direct learning to other projects, and other kinds of diffusion of lessons learned. Both kinds of learning contribute to the aggregation of knowledge in a socio-technical system, new networks, and possibly changed expectations. According to Raven (2005), experiments should be carried out in ways that contribute to such processes of disseminating knowledge. This can contribute to the development of the socio-technical system for use of solar PV technology at different societal levels – locally, regionally, nationally and internationally.

By implementing many projects in different villages, WBREDA went some way in replicating their model and thereby in exploring its replicability. The standardization of

[43] Solar home systems also have their limitations and challenges in terms of the investment costs for the users, battery maintenance, the need for purchasing new batteries with a few year's intervals, and limited hours of supply.

[44] 63% of the mini-grid customers interviewed in the survey had electric light in the kitchen (Winther 2014).

various elements of the socio-technical design and the attempt to use private companies as contractors were measures taken in order to make it possible to implement and follow-up a larger number of projects than they could handle alone. The initiative for creating a cooperative that could be responsible for several mini-grids in one geographical area (10 mini-grids on Sagar Island) was another way of making arrangements for coordination of many projects/local systems. The challenges for making these arrangements work, as shown in earlier parts of the chapter, constitute potential challenges for replication on a larger scale.

A further challenge that would have to be solved in case of further replication was the arrangement for covering the costs for operation and maintenance, both by finding ways to improve the economic performance, and by making sure that funding for some of the operation and management costs could be available for the power plant, since it could be difficult to fully achieve economic sustainability.

Another activity by WBREDA that could be seen as a kind of replication was the other power supply systems they implemented in parallel with and after the solar mini-grids (implementation of solar power supply at many schools in the area, provision of subsidized solar home systems as well as a large biomass gasifier mini-grid on Gosaba Island). The lessons WBREDA drew from the solar mini-grids most likely had an impact on the kinds of activities they chose to carry out, and how. Another project that directly learned from the projects was a solar mini-grid project in another island in the Sunderban region, implemented by WWF. They tried out technical and organizational measures to solve the challenges encountered by WBREDA on over-use and lack of payment through a new type of electricity meter and a different type of community organization (Huseby 2012).

There are probably several other projects/programs that have taken lessons from the WBREDA mini-grids, through actors who have transferred lessons to other projects, including policy makers and project implementers, including those involved in the Kenyan project analyzed in the following chapters.

The general diffusion of lessons learned might have been widespread, since the projects became famous early on, as a "success story" and the initiators were active in spreading information through media, workshops, policy, discussions, a book, etc. The projects received much praise in early years, including the Ashden Award in 2003. Several kinds of actors have visited the projects and researchers from many disciplines have studied them. Lessons have been learned both on how something could be done and on which problems might be important to avoid. One of the central WBREDA officials expressed that he and his colleagues have learned a lot through their work in the Sunderban, not least on the importance of the social aspects of the systems.

5.7. Chapter conclusion

This chapter has shown a range of socio-technical dynamics and learning processes in village level solar power provision, and provided insights in aspects that play a role for the usefulness and long-term viability of such models. At the same time as giving insights in the substance of the projects, the case has also demonstrated factors that may have importance for learning and innovation in socio-technical experimentation in niches. As pointed out by

WBREDA officials, they had undergone a long learning process, and met many unexpected problems underway.

The initiators of this socio-technical innovation process had high visions and important capabilities, and they had the courage and skills to develop and implement new socio-technical designs in a serious attempt to create new social structures. They also had the ability to get a range of other actors on board in various ways (national level government actors, equipment suppliers, the state government, and local governments), and secure financing and human resources for the implementation of their ideas. A range of different factors thus defined the structural space (or room for maneuvering) within which the implementing actors could apply their creativity.

The solar mini-grids gave access to basic electricity services of interest for households, businesses and other users. The trust-based system with flat rate tariffs constituted a practical model that provided important incomes for operation and maintenance in early years, but also gave openings for creative uses of electricity, but in "unruly" ways that affected the whole system. The electricity users' practices gradually developed in ways not anticipated initially and the already implemented socio-technical configurations strongly limited the kinds of improvements the involved actors could make.

The local socio-technical systems became a normalized part of the local communities, and changed the community members' expectations to the use of electricity. The positive achievements in terms of providing important services had paradoxically contributed to making the users dissatisfied and drawing as much power as they could, which in turn affected the functioning of the system. It put pressure on the technically weakest link, the batteries, and contributed to reduction of hours of electricity supply. The technical weaknesses and constraints of available equipment (and lack of flexibility in terms of gradual expansion) were outside the control of the project implementers and influenced most of the local socio-technical system. The technical weaknesses had to be compensated for through the social organization, including a large responsibility and difficult tasks for local committees and operators.

Since the operators played key roles, their skills and motivation were important for the level of performance at the different power plants. Their motivation seemed to be influenced by salary levels, follow-up by contractors and project implementers, and working conditions, among other things. However, they were not in a position to influence neither the factors that led to over-use of power, nor the reduced willingness to pay for the services. The task was also difficult for the local committees and organizations in charge. Economic sustainability became difficult, but affordable electricity services were provided for significant portions of the community members in each village, including those who had access through other people's charging of batteries for them. There were spatial challenges due to the outreach and specific routes for the gridlines in the mini-grids, although less than what is common in conventional grid extension.

In addition to the users of the electricity, the other involved actors (local committees, contractors, operators, etc.) also developed their roles and practices as part of the socio-technical system, differently from what had been planned and anticipated. WBREDA depended on the willingness of these other actors to do a good job, but they tended to have insufficient commitment for their roles. The projects could possibly have functioned better if WBREDA had been able to follow up the projects more directly – more "hands-on", instead of trying to make middle actors take care of the projects. A more hands on approach would also have entailed challenges, like need for more staff and ensuring their commitment, but could possibly have been easier. The emerging outcomes of the socio-technical innovation process led to continuous adjustments by the implementing agency, while the main characteristics of the model remained the same.

Instead of the high visions and inspiration that had been prominent initially, it seemed like the work of the implementers was now to a larger extent driven by duty as well as pressure from the electricity users, operators, and other local actors, as well as external observers. This was also related to the changing policies that seemed to make the projects less relevant and future oriented. The Sunderban projects had gone from being celebrated by all observers, including researchers and policy makers, to becoming an example of an experiment or pilot project which was hardly seen as a model for replication and upscaling, due to its challenges in economic and technical performance (changing the expectations of niche and regime actors). As noted in studies of community energy in the North, the projects struggle to survive and economic sustainability is a challenge (Seyfang and Smith 2007). This indicates that efforts for deliberate social and technological change is hard work that might give frustration, be expensive and lead to criticism of those people who took responsibility and tried.

However, the Indian framework conditions could allow for further implementation of solar mini-grids. A comprehensive activity that has some similarities with the WBREDA model, is the implementation of so-called "solar micro-grids" (or small mini-grids) implemented and operated by Chhattisgarh Renewable Energy Development Agency (CREDA) in hundreds of remote villages in the state of Chhattisgarh in India (Millinger et al. (2012). CREDA learned from WBREDA according to a leading expert on the solar PV work in India. The CREDA model was standardized, simplified and smaller than WBREDA's Sunderban model, and provided very basic electricity provision. Starting from 2002, these were funded through the Ministry of New and Renewable Energy's program for Remote Village Electrification (RVE) and the state government. They were managed through an institutional framework and system for operation and maintenance made up by government offices at different levels of governance, under CREDA. Economic sustainability was neither seen as possible nor necessary here. The costs for operation and maintenance were partly covered by the revenue and partly by funds from the implementing agency (the government). Affordability and operational sustainability were central aims. The actual functioning and quality of electricity access achieved in these activities is beyond the scope of this discussion. However, the example illustrates that the national framework conditions in India does allow for some kind of replication of solar micro- or mini-grids, at least for state governments.

Chapter 6: The Kenyan case (I): Framework conditions and visions

This is the first part of the analysis of the Kenyan case, which includes the process of transferring knowledge from India to Kenya. The analysis follows a similar structure as the analysis of the Indian case, but it is divided into three chapters, because it is based on continuous participation and observation over years instead of a concentrated fieldwork. The long-term participation gave a special opportunity to analyze learning processes involved in activities for socio-technical change. This chapter, through analyzing the first phase of this process, continues the two interrelated and mutually supporting levels of research in this dissertation, providing insights both on the social organization of village scale solar power supply, and on how such knowledge can be transferred between different geographical contexts.

In the action research in Kenya, instead of generating knowledge by studying other people's trying and learning, as in the Sunderban case, the way of generating knowledge was here through one's *own* trying and learning, doing similar kinds of work as that of the people who had been studied in India. This was according to the constructive research approach chosen, as described by Kalleberg (2009). The previous chapter demonstrated one way of doing constructive research – studying existing examples of social actors' efforts for social change and see if there is something to learn from these.

This and the next two chapters on the Kenyan case demonstrate another way – combining social science insights with the knowledge and practical experience of various social actors through real life efforts for social change. Underway in the research process, the researcher had the responsibility for solving real life problems, in cooperation with others. The academic knowledge was both applied and developed through the process, and the knowledge was co-generated through the interaction with other social actors, as explained in Chapter 4 on methods. While the methods for data collection on the action research process in Kenya were described in Chapter 4, the details of the practical steps of the process are included in this analysis of the Kenyan case, since these constitute both the project implementers' actions and practical steps of the action research at the same time

A basic assumption for the activity was that locally-based energy supply has to be organized differently in different geographical contexts. The aim for the team of practitioners and social scientists was to combine the findings of the case study in India with research on various aspects of the Kenyan context in order to provide knowledge on how the Indian model could be made suitable here, combining research results with the practitioners' experience and community members' ideas and local knowledge. It was also seen as important to keep the socio-technical nature of local electricity systems in mind throughout the transfer process, as well as their embedding in societal contexts and the Kenyan electricity regime in addition to ongoing socio-technical innovation on off-grid power supply based on solar PV and other renewable energy technologies.

Table 6 below outlines the activities that made up the Kenyan project, including the transfer process. The stepwise activity for the transfer and adaptation of the Sunderban solar mini-grid model to a Kenyan context was conducted both before, during and after the case study in India. The ideas for the socio-technical design of a power supply system emerged gradually, and were influenced by the emerging understanding of the contextual conditions in Kenya. These contextual conditions were, firstly, the national framework conditions for use of solar PV technology in Kenya (corresponding with the dimension A of the case study framework). These framework conditions, which have linkages to the international solar PV trends, are discussed in this chapter, which also shows how the selection of a place in Kenya for the project took place, and how the learning from India was experienced. Secondly, the local socio-cultural and socio-economic context was important (corresponding with dimension B of the case study framework). This is discussed in Chapter 7, together with the development of the socio-technical design for a Kenyan village, the way the model looked on the drawing board before it was tried out in practice (corresponding with dimension C). Finally, how the power supply model came to work in practice (aspect D) and the quality of the electricity access that the pilot project offered to the users (dimension E) are discussed in Chapter 8.

Table 6. The main activities carried out for the development of a power supply model in Kenya.

	The activities that made up the Kenyan case, including the process of learning from India	*2006-2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Ch. 6	Preparations with Kenyan energy experts						
	Research and study tour in India, analysis						
	Selection of place in Kenya						
	Studies of the national context in Kenya						
Ch. 7	Studies of the local context in Kenya						
	Cooperation with Kenyan village						
	Development of system design						
	Procurement, training, start-up						
Ch.8	Follow-up, support and advice, local level						
	Research on how the model fared						

Although each step built on previous steps, the activities overlapped each other in time and there was much interaction between them, as will be explained. Despite the anticipation that contextual conditions would influence the composition and working of the power supply model, the differences between the Indian power supply model and the model developed through action research in Kenya became larger than the team had expected.

Theoretically, the Kenyan village-level electricity project that came out of this process can be seen as a hybrid between grassroots innovation and a bounded socio-technical experiment. Similar to many grassroots innovations, the Kenyan project was grant funded, and an intermediate actor (which the project team can be seen as) assisted a local community on the project – i.e. experts and a local community joined forces. Also similar to grassroots innovations, the project was not oriented towards the commercialization of a niche technology, but motivated by social need. However, an eye was kept on the potential of village level electricity systems to become commercially profitable and attract interest from businesses or entrepreneurs.

An important difference between the action research project in Kenya and grassroots innovation was that the initiative came from the project team, not from the community. Community representatives were asked if they were interested in participating in the project. Although they expressed strong interest in the project, they did not initiate it. The planning and implementation process was also led by the project team, in close cooperation with the community. After implementation the project depended to a large extent on the community members who managed, operated and used it, although the team continued to provide support.

Similarities between the Kenyan project and bounded socio-technical experiments were that the project was initiated by a temporary project team, with researchers and practical experts. It was also a small project, limited to a village (and gradually the surrounding villages). Emphasis was put on learning processes for involved actors, and on diffusion of the learning to actors outside the experiments, including government actors, the private sector and NGOs. The learning was going on at the micro level of the project team in interaction with a village community, and in interaction with a wider network. A difference was that the role of social scientists was larger and more central in the Kenyan project than they seemed to be in the bounded socio-technical experiments described by Brown and Vergragt (2008). Another difference was the systematic transfer of lessons across projects on different continents as part of the activity. The analysis of the Kenyan case therefore has the potential to provide insights on factors that influence the learning processes in similar activities as grassroots innovation and bounded socio-technical experimentation, spatial transfer of socio-technical innovations, and possibly in some ways also in socio-technical experiments in general. The team itself did not see the activity in Kenya as a socio-technical experiment, just a pilot and demonstration project.

6.1. The Kenyan energy sector and actors as a starting point and backdrop

The planning and considerations on the pilot project in Kenya started long before the research in India. The idea for the learning from India had appeared during interaction with renewable energy experts in Kenya from 2006 onwards, and this interaction continued and increased as the project came into being. Although the use of solar PV is still a small part of the electricity generation in Kenya, the country has been a pioneer in the field of solar PV in Africa for nearly three decades (Jacobson 2007, Byrne 2009, Ondraczek 2013)

The main uses of the solar PV technology have been in solar home systems, but also at boarding schools, health clinics and other kinds of individual buildings, tourist lodges, hotels and in water pumping projects. In addition to such off-grid uses, some grid-connected solar PV systems have been installed in Kenya in recent years.

There was no solar mini-grid or other village-level solar power supply system in Kenya at the time of planning this activity, while a few other initiatives emerged during the project period. There were a few mini-grids where the power was generated by other technologies than solar PV in villages in different parts of the country, including micro hydropower. Several of the Kenyan team members had been involved in practical implementation or academic research on some of these mini-grids. This experience of mini-grid configurations was among their reasons for being interested in a mini-grid project that could use solar power. The solar PV technology was very well known by them, but a pilot project on solar mini-grids would provide an opportunity to explore new ways of using the technology and to work on typical organizational, economic and operational challenges that they had seen in previous mini-grid projects. The idea of developing a pilot project on solar mini-grids was seen as useful in order to make progress in the field of solar power, as well as on renewable energy and off-grid electricity supply in Kenya in general. This view was expressed by the team members as well as by government representatives and other actors in Kenya outside the team who were working on renewable energy and rural electrification.

6.1.1. The government's work on providing electricity to the people in Kenya

An important backdrop for the team's planning of a pilot project in Kenya was the general work on rural electrification in Kenya. The Kenyan policy framework came in as a natural part of the discussions on how the solar power supply model should be configured, often brought up by Kenyan team members. Other kinds of framework conditions, like international trends in the solar PV field – especially price changes and types and qualities of equipment available – were also noticed underway, through interaction with industry actors and through news and updates in international workshops and on the internet from industry actors, associations and NGOs in the renewable energy field.

The electricity grid in Kenya reaches a small portion of the population, like in many other countries, in Kenya's case around 16% (IEA 2011). In rural areas it is around 5%, and in urban areas 50% (Republic of Kenya 2010). The number of consumers increased by 139% between 2005 and 2011 (Ministry of Energy 2012), but the people who are connected to the grid are concentrated in the larger cities and towns and in central areas of smaller towns. The challenge for the authorities in Kenya, similarly as in India, is that the costs of providing electricity in rural areas are higher than in urban areas because the customers are scattered over a wide area, access to the settlements is more difficult and the use of electricity, and thereby the revenue is very low. The costs of operation and maintenance are also high.

Furthermore, 25% of Kenya's population of 40 million in total live in the arid and semi-arid lands which represent 88% of the country area.

The work on extension of the grid is gradually reaching further out, stretching power lines through towns and along main roads. However, only a small part of the households and businesses decide to connect to the grid even if it comes to their area, (according to a Kenya Power official and Kenyan energy experts). Reasons for this are that it is expensive to connect, that extra transformers and lines from the main grid to the customers must be covered by the customers themselves if they are more than 600 meters from a transformer, and that the monthly electricity fee is also difficult to afford. The connection fee in 2013 was 35,000 Ksh (293 Eur) for all customers within 600 meters radius from the transformer. This was revised in 2014 such that only customers that do not need any additional poles pay 35,000 Ksh while all the others pay exact cost for stretching the grid to their house, which is much higher than that. A hurdle is also the installations required in the customers' buildings and the need for the customers to purchase electric appliances.

The investment required to subscribe is disproportionally large compared to the few services that people require from electricity initially. There is also a category of small businesses that operate from temporary structures that cannot qualify as per Kenya Power standards to be connected to the electricity grid. Kenyan experts on renewable energy and off-grid power supply therefore argue that many people are in need of off-grid solutions to get light and other basic electricity services even in areas where the grid power is near or already present. However, a large number of people in Kenya are still without electricity access or access to solar power supply - around 31 million according to the World Bank and IEA (2013) or around 6,7 million households (Republic of Kenya 2010).

There are no specific support mechanisms in Kenya for provision of electricity for households, neither through on-grid nor off-grid solutions. Thus there is no Kenyan parallel to the Indian program for lighting households in remote villages. It is rather an explicit policy in Kenya that subsidies or support to individuals or households for connection to the grid or solar home systems is not given. Households are supposed to be served by the normal grid extension or through the private market by their own purchase of solar lighting systems or other private solutions.

The priority of the government is to electrify public facilities (district headquarters, administrative institutions, commercial infrastructure like trading centers (markets) and rural towns, public educational institutions (secondary schools and other post-primary institutions) and public health facilities (dispensaries, health centers and hospitals). According to Kenyan energy experts typical commercial subscribers to the electricity grid are shops/retailers, small restaurants, service workshops (repair shops, battery charging shops), cooking and conservation of drinks and food, tailor shops and hair dressing. In addition, there are handicraft and small-scale industries characterized by high power demand, e.g. agro-processing (i.e. husking, milling, threshing and oil pressing), wood processing, wood and metal works. Electricity is also used for water supply and public lighting.

Kenya's power generation is done by several types of generation facilities.[45] For grid connected generation (in 2012-2013 nearly 6000 Gigawatt hours (GWh)), there is a mix of hydro-power, "thermal' (fossil fuels), and wind. Between 2007 and 2013 hydropower fluctuated between 60 and 72% depending on rainfall. The use of diesel and other fossil fuels, fluctuated between 8 and 16% during the same years. Geothermal power varied between 18 and 26% during this period, and wind was below 1%. For the governments' off-grid power generation (in 2012-2013 27,3 GWh), which mainly consists of the "isolated power grids" described below, the generation was based on 100% diesel up to 2011, before solar and wind power started to appear partly as a result of activities described in this dissertation. The power supply in Kenya is vulnerable to drought periods because of its dependence of hydro power, and it is vulnerable to price increases for fossil fuels due to the large use of these (Newell et al. 2014).

6.1.1.1. The organization of the power sector

The Ministry of Energy has the main responsibility for development of energy policy and programs, including the field of renewable energy and off-grid installations. The Ministry also directly implements some projects in the field of renewable energy, after the Energy Act of 2006 initiated a new energy policy in Kenya, which increased the attention to renewable energy. Actors in the renewable energy sector made an effort to influence the law during its writing (Byrne 2009), and achieved some "empowerment" of the niche in this way. Around this time the Ministry of Energy started the Institutional PV Systems Program, under which they install solar PV systems in schools and health clinics. Rural Electrification Authority, mentioned below, also has a similar program.

Regarding rural electrification in general, the law of 2006 led to the creation of the Rural Electrification Authority (REA) which started operating in June 2008 in its current form, building on the Rural Electrification Program which was established in 1973. The Rural Electrification Master Plan was completed in 2008 in order to guide the work of the REA, which receives funds from Ministry of Energy and Rural Electrification Fund collected by Kenya Power (earlier Kenya Power and Lighting Company). Its mandate is to promote and facilitate the development of rural electrification projects and services that improve access to modern energy services. The fund is a financial instrument that Rural Electrification Authority uses for capital subsidies for project developers and for other ways of stimulating the development of rural energy projects. The fund is financed through a levy of 5% on the electricity bill.

REA mostly concentrates on conventional grid extension and diesel fired mini-grids, but is also gradually entering into the field of off-grid renewable energy supply. Kenya Power is the national power utility in Kenya. It is a company owned by the state and private sector shareholders. The company distributes the power to the subscribers and operates according to commercial principles, and is the only power distributor in Kenya. A new electricity law is proposed, which will remove Kenya Power's monopoly in using the power lines. A system

[45] The statistics on Kenyas power generation presented in this paragraph are accordning to Kenya Power's annual reports from 2007 to 2013 (http://www.kplc.co.ke/content/item/40/Annual-Reports-Archives).

operator will own the power lines and companies that get licenses for distribution can use the power lines. The Energy Regulatory Commission (ERC) is responsible for economic and technical regulation of power and renewable energy, on tariff setting and review, licensing, enforcement, approval of power contracts with independent power producers, etc. Furthermore, Kenya Electricity Generating Company (Kengen) is in charge of all publicly owned power generation plants in Kenya, except for some isolated power grids as described further below. Kengen was separated from Kenya Power and Lighting Company in 1997 as one of the changes done during a process of unbundling generation from transmission and distribution of electricity.[46]

All these public and public-private organizations involved in power supply in Kenya represent both the conventional, established activities in the electricity sector (the "electricity regime") and emerging activities related to new, renewable energy technologies ("niche" activities on various emerging socio-technical systems). The renewable energy sources that are worked on in Kenya include off-grid and grid-connected wind power, modern bio-energy of various kinds, solar energy, geothermal energy and small hydro power. Geothermal energy has a special and strong position because of its large scale, centralized and stable production of power based on Kenyas resource in this field (Newell et al. 2014). Ministry of Energy has a separate department for renewable energy and the Rural Electrification Authority has officials who have the responsibility for renewable energy projects. Kenya Power is involved in renewable energy installations, since 2010, through their involvement in the isolated power grids as explained below. Institutionally, there seems to be a close connection between the established "regime" of modern energy supply and emerging "niche" activities on new renewable energy in Kenya.

There seems to be an overlap between the work of Ministry of Energy, REA and Kenya Power, in terms of installing or supporting solar- and wind power. This sometimes leads to some uncertainty of who is responsible for new initiatives in the field of off-grid renewable energy, but also close interaction. A possible positive effect may be that staff in several different government organizations gradually gets experience of planning, implementation and follow-up of different kinds of renewable energy systems and policies. However, the off-grid renewable energy field (which could be seen as niche composed by separate niches of solar PV, wind, biomass, etc.) is still a tiny part of the governments work, except for geothermal energy. There is pressure on the government to drastically increase power generation in the country in order to fulfil the increasing demand for power among power consumers within urban areas, including industry. The focus is on adding megawatts and this probably leads attention away from solutions where a few Watts can have large importance for people's quality of life in terms of access to electric light and other basic electricity services (Newell et al. 2014).

[46] Kengen website, http://kengen.co.ke

6.1.1.2. Incentives for renewable energy

There are tax incentives to producers of technical equipment for renewable energy technologies and fiscal incentives to financial institutions to offer credit facilities to consumers and entrepreneurs. There was duty and VAT exemption for specialized solar equipment and accessories for a period, but this exemption was repealed when the VAT bill was reviewed in 2013. This was part of an approach by the treasury to implement a blanket removal of all VAT exemptions.

The use of solar power in off-grid systems in Kenya can be seen as a dynamic and evolving "niche" sector (a niche that is part of a broader off-grid renewable energy niche). It is not as diverse as India's, and with fewer government initiatives and support mechanisms, but with the private market as a driving force. Moreover, also donors have been (and are) drivers of the solar PV development in Kenya, and has contributed to the development of the private market which is described after the following section (Byrne 2009).

6.1.1.3. The isolated power grids

During the project analyzed here, there was often mentioning of Kenya's isolated power grids in remote district and county headquarter towns during the team's planning process. The isolated power grids are not the same as the Kenyan village-level mini-grids mentioned above. These separate grids (also called regional or district grids) are part of the government's work on rural electrification and located in areas far from the national grid. These grids supply power for 24 hours per day, mostly from large diesel generators, and are thereby very different from the much smaller Sunderban mini-grids. The power supply stations are operated by professional technicians hired by Kenya Power, and subscription and payment is done in the same way as for the other electricity supply from the national grid in Kenya.

There were 14 such isolated grids in Kenya in 2009.[47] By 2014 there were additional 4 isolated grids in operation,[48] and 13 more under construction.[49] This power generation is more expensive than that of the main system, because large amounts of diesel is needed, and the costs for the diesel and its transport become high. For the power plant in Lodwar for instance, two large trucks delivered the fuel every second day as per November 2009 and the trucks spent two days on the road driving from Nairobi to Lodwar (700 km of bad road), using large amounts of fuel also on the way. The cost of maintenance for the high speed diesel engines is also very high, according to the chief engineer for these plants.

The costs of operating the isolated power grids are sometimes described as a burden on the electricity sector by Kenyan energy experts. While the customers of these grids pay the same tariff as the customers of the main grid, the extra costs of operating them are passed on to the subscribers of the main grid. The policy is that those who have a connection to the main grid should contribute to the provision of power to those who are connected to the

[47] The isolated grids operated by Kenya Power are in Merti, Lodwar, Habaswein, Hola, Wajir, Mandera, Moyale, Marsabit, El Wak, Mfangano Island, Baragoi, and Mpeketoni.
[48] These were located in Lokichoggio, Rhamu, Takaba and Eldas.
[49] These are located at Faza, North Horr, Laisamis, Lokitaung, Lokori, Hulugho, Kiunga, Daadab, Banisa, Kotulo, Kholondile, Lomokori and Kamolibard.

isolated grids, as well as to the extension of the main grid. A levy is therefore charged from all Kenya Power customers for the fuel costs in the isolated grids and in the thermal stations in the grid ("the fuel adjustment cost") and this levy varies according to actual fuel expenses. A levy of 5% for funding of further grid-extension is also added to the power bills of all customers. During the travel to India together with some of the Kenyan contacts, the person from Kenya Power responsible for most of these power plants was humoristically teased by other Kenyan participants for being in charge of this, and for "increasing their power bill".

6.1.2. The private sector solar PV market in Kenya

Kenya is one of the world leaders on per capita installation of solar home systems and one of the most dynamic commercial PV markets in Africa (Jacobson 2007, Byrne 2009, GTZ 2009). Solar systems purchased by Kenyan households constitute about 40% of the solar home systems sold in Africa, and 10% of the global market for solar home systems, according to (Ondraczek 2013). Approximately 320,000 solar home systems had been sold in the country by 2010 (cumulative), and the sales per year were estimated to be 20-25,000 (Ondraczek 2013). Although solar home systems are common, and most Kenyans know what a solar system is, there is a small portion of the households in Kenyan villages that owns one, because it can not be afforded by the majority. According to the (Republic of Kenya 2010), 2% of the rural households in Kenya answered that they used solar power as a source of lighting in 2009.[50] Up to 4.4% of rural households had purchased an Solar Home System by 2011, according to Ondraczek (2013).

The annual growth rate for sales of solar PV systems in Kenya has been around 10-15% since the 1990s and the demand for solar home systems has been a major part of this. The rest of the solar PV market is constituted by community systems (water pumping, power supply at institutions), telecom and tourism. Some of this is installed by NGOs/missions and government organizations (GTZ 2009). There are no statistics for how many of the solar PV systems that work. It is likely that some of the systems are not working because they have reached the end of their technical life or due to lack of maintenance and battery replacement. The private market has led to the development of a strong "consumer chain" for supply and installation of solar systems all over Kenya. This has mostly been for systems below 1.5 kW. There were 15-20 major suppliers of solar equipment in Kenya in 2009 and hundreds of sales agent companies (GTZ 2009).

The buyers of the solar home systems have been mostly "rural middle class" people who purchase them over the counter (Jacobson 2007). These are small business owners, rural professionals such as school teachers, civil servants, pastors, and the better off among the smallholder cash cropping farmers within coffee, tea and horticulture (Jacobson 2007, GTZ 2009)

Studies of the residential market for solar PV systems in Kenya have given insights in the actual use of solar power in the households. It has been shown that the use of the solar home systems have importance for communication and connectivity between rural and urban

[50] Kenya Population Census data 2009, Kenya Bureau of Statistics 2010.

people (Jacobson 2004). This is because the solar power enables people to watch TV, listen to the radio, and use mobile phones, and thereby to increase their interaction with people, markets and ideas in urban centers. Light for education related purposes (i.e. for children to read) is shown to have less priority than what is often assumed. An important motivation for the purchasing of a solar home system is often use of TV. The consumption of power for this tends to compete with the use of light in the households. This is due to the very limited amount of available power. So-called "intra-household dynamics" play a role here – where watching of TV gets higher priority than the use of light for reading and writing (Jacobson 2004). However, in some of the households, education related uses are a key application of the solar home system, including school teachers' grading and planning of teaching.

These findings on which kinds of electricity use are prioritized and who uses the power are an interesting background for the pilot project carried out in this project, of which renting of portable, electric devices for lighting became a central part. The cases analyzed in this dissertation show how different organizational models, socio-technical designs, and scales of delivery facilitate different kinds of electricity access, different ways of using the solar power and perhaps also reach different kinds of users including different family members.

A trend that was observed underway in the project period was a change in the international as well as the Kenyan market from a dominance of conventional solar home systems, which are often designed and installed by qualified solar technicians, to solar lanterns and other smaller, and cheaper systems that are based on "plug and play"- principles. A large variety of such solar products for individual users appeared in the market with a wide variation in (and often poor) technical quality, lighting output and life time, and in many different price ranges. These systems have made the solar PV technology more affordable (they have LED lights that require less power and thereby smaller solar PV panels), easier accessible, easier to install and easier to maintain. They need battery replacement every 1-4 years, but the batteries are also cheaper than for the larger systems. However, despite more affordable products available, they are far from affordable for all, as this research indicates.

This and other trends and characteristics of the energy sector in Kenya influenced the team's considerations on how the pilot project should be designed. A central assumption was that households that are not able to benefit from neither grid extension, nor solar home systems or solar lanterns, might be reached by a village-level power supply, and such a system could also offer other electricity services in addition to light. The individual users would not have to take on a financial burden to invest in their own power generation, and the challenge of maintaining the equipment.

6.1.3. Exchange of information between the project team and relevant actors in Kenya

The project team met with some energy sector actors in Kenya before and during the project period, from 2007 onwards, in order to present the teams' plans and results, get comments and inquire about the government's work in related areas. Several brief meetings were held with directors and advisors of the Department of Renewable Energy at the Ministry of

Energy. They expressed support for the team's plans for trying out a solar mini-grid model in Kenya. The Kenya Power official mentioned above, took the initiative to several meetings with the team leader, after hearing about the project through one of the Kenyan team members. He was eager to link up with the team and combine his ideas about solar power with the ideas and plans of the team, because he saw potential synergies of such cooperation. Thereby, he became a natural person to invite for the event in India in 2010 and was later taken up as team member. Two other Kenyan government officials were also invited to India, but they could not attend.

Team members visited the REA during the early phase of the work in Kenya, and asked whether the planned pilot could fit under the support-mechanisms for off-grid renewable energy projects. They answered that they do support such projects, but not research projects. Team members also visited other government agencies, including Arid Lands Resource Management Project and NEMA (National Environment Management Authority). Meetings or conversations in workshops were also held with development agencies and NGO's (including Norwegian Church Aid's East Africa office and GTZ), renewable energy organizations and companies (Solar Net, KEREA, Sollatek, Kenital Solar, Telesales, Sun Transfer, Westlite Solar, and others) and university representatives.

The early parts of the planning and discussions on the practical project, both with the team members and others did not touch much upon the specific aspects of the model to be implemented in a Kenyan village. The focus was rather on how it could be possible to implement it, where in Kenya it should be done, with whom, and financed by whom. There was also mention of who could follow up the pilot project in the long term perspective and who could potentially replicate it.

The main outputs of the meetings were mutual exchange of information and awareness of each other's work, and creation of linkages with some of the people met. A county level representative for the Ministry of Arid Lands in Kitui later became an important contact for the planning at the local level. The interaction with various actors in Kenya outside the team continued over time, but to a smaller extent and in different ways than during the first three years, and it became more oriented towards sharing of results.

6.2. The project implementer's role and visions

The characteristics of the process analyzed here was strongly influenced by the people who created it, their background, their ways of cooperating, and their visions for the outcomes, as was also the case in the Sunderban projects implemented by WBREDA. As mentioned in Chapter 2 on theory, the focus in this research is on the actor's activities on the ground and how they try to develop ways of making technologies useful in practice. Their work takes place within a room for maneuver influenced by societal structures and contexts, including the wider solar PV sector at the national and international level.

6.2.1. Characteristics of the project implementer

While the Indian project implementer was a government agency, a research team was here in charge of the activity. Network formation and cooperation between different kinds of actors has been pointed out as important in relation to socio-technical experimentation and learning processes, in terms of having team members who represent both the established socio-technical systems (regimes) and the emerging ones (niches) (Hoogma et al. 2002, Loorbach and Rotmans 2010). The team described here was not heterogeneous in this sense since all participants could be seen as "niche actors". However, it was so in terms of being international and trans-disciplinary, and bringing together different kinds of background experience within the fields of solar PV and rural electrification. Some team members had good insights in conventional electrification, but did not represent interests or organizations within that area. A "regime" representative (a representative of the established system for power supply in Kenya) later joined the team on his own initiative, and became important.

The eleven (later twelve) team members represented organizations or consultancy companies in India (one), Kenya (five, later six), Austria (one) and Norway (four). These included four practitioners, five social scientists and two who were a combination of these. Among the Norwegian and Austrian participants, the social scientists were in majority, and among the Indian and Kenyan participants, practitioners were in majority. Several of the practitioners had significant experience with implementation of power supply of different kinds, in many countries (India, Kenya, Tanzania, Uganda, South Africa, and other countries). According to this research, it would not have been reasonable to develop and implement a social science led technology project in Kenya without such practitioners. There was no equipment supplier in the team, since this was not seen as relevant, although the option was explored as part of the work to raise funding for equipment. The main idea was to purchase the equipment in Kenya as part of embedding the project in ongoing work in the country.[51]

6.2.2. The visions and objectives for the solar power supply model

Development of common, guiding visions and expectations for the short and long term perspectives has been pointed out as an important part of strategic activities for socio-technical experimentation and innovation (Brown and Vergragt 2008, Loorbach and Rotmans 2010). Team members in this case joined the team because they shared interest in ideas formulated from the outset of the project. The common aim was to develop and implement a solar mini-grid model in Kenya, based on learning from the Sunderban solar mini-grid model. The team would then adapt the model to the Kenyan context, in close cooperation with a village community. In addition to this plan, the team shared a vision that the Kenyan model would provide an example that could be replicated or built upon in Kenya, and even in other countries. Team members also had more general visions about a green and equitable future, which would thereby be radically different from the current state of the global society. The

[51] One of the Kenyan team members changed from focusing mainly on academic research to becoming a business person importing a specific brand of solar lanterns and home systems. He promoted these products to the team, and the team gave him a chance to try out a few lanterns as part of the project, but the villagers preferred other kinds of lanterns.

use of solar power could be one of the solutions that could help to solve pressing problems of poverty and vulnerability and lack of environmental sustainability. Electricity access for a large number of people was a central part of this overall vision. A sense of urgency was present, which is pointed out as a driving factor for stimulating processes of trying and learning (Brown and Vergragt 2008). The team shared these main visions from the start of the project, according to their statements during the first project meeting.

Other ideas and visions supported by the participants from the outset were that technological change for future sustainability has to be adapted to everyday practices and requirements that come up under daily use. Such adaptation of technologies to social life could also inform the development of institutional frameworks that could support the use of new technologies (Ornetzeder and Rohracher 2005). The Kenyan model developed by the team could contribute to a diversity and variation of possible solutions for more equitable and green energy systems for the future.

A technology specific approach was seen as useful and necessary in order to explore and understand specific options for future energy supply. Solar PV technology used at the village or community level was suggested before inviting the team members. Everyone who joined the team did so in awareness and support of this choice. The local community in Kenya that was invited to work on the project was informed about this focus, and supported the idea of exploring how they could benefit from the abundant solar resource of their area.

Despite such initial choices and "closures" for the project, there was still space for being innovative and for having an open approach, because little, if anything, was decided about the details of the Kenyan solar mini-grid model. For example, it was not yet decided which kinds of electricity services the solar power supply model would provide, how many people could be reached, which sizes of solar installations that could be suitable, how large investments could be possible, or who should operate the power plant. The common challenge for the team was to find suitable answers to these questions by developing a socio-technical design that could suit, and solve typical challenges found in existing cases, including the Sunderban example. The personal motivations of each team member was both the guiding visions mentioned above, and work opportunities through project funding and business.

6.2.2.1. Objectives for the qualities of the power supply model

In addition to the common visions and open questions to explore, the team also had some more specific objectives or visions for the desired *qualities* of the power supply model, which seemed to be largely in common from the outset. These can be seen as more operational visions than the more general and overarching visions mentioned above. The objectives were not much discussed in themselves, nor clearly defined. Some goals were mentioned in the initial project description, and thoughts came up underway. But there were long-standing considerations during the project period on what the model should look like. These were implicitly based on objectives for the kinds of qualities the model should have and how these could be achieved – i.e. what the objectives would mean in practice. The team members mostly shared the following seven objectives, which had commonalities with the aims of the WBREDA officials in India and many others actors in the same field.

Firstly, the power supply model should provide affordable electricity services for people and in other ways ensure *broad access* to the services. This was talked about in terms of how the solar power supply model could provide services that would be available for as many as possible of the community members, preferably all, regardless of their economic situation or their geographical placement in a village. However, there was also an understanding that it might be unrealistic to reach all. Broad access would also mean that people of both genders, at different ages and in different life situations could be able to utilize the electricity in ways that could be useful for them.

Secondly, there was much interest in developing a model that would be *economically self-sustaining*. This means that the power supply should generate enough revenue to cover all necessary costs of operating and maintaining the local power plant in the long term perspective. A potential surplus could be saved for expansion (to reach out to larger areas and more people) and other improvements of the system. A surplus could alternatively (or in addition) be used for community purposes (general improvements in a village). Economic self-sustenance was seen as important in order to give economic independence for those people or organizations that operate the system. They should be independent in the sense that they could pay their expenses through their own funds. Dependence of funds from others for operation and maintenance could give delays in maintenance activities, or funds might be unpredictable or stop coming, and thereby create serious problems and breakdowns.

Thirdly, the model should of course also be viable in all other ways. *Practical, well-functioning operations and maintenance* was talked about in terms of good and manageable daily routines that should be created for and by the staff/operators and that the economic transactions should be done in an orderly and transparent way. The training of the staff should be done in a suitable way, the system should be technically robust, people's use of the services should be done in ways that would not undermine the system, and the staff should have easy access to spare parts for the technical components. This is sometimes called operational sustainability.

Fourthly, there was agreement in the team that it is important to take very seriously both the *gender aspects* and the *local and national context*. Women's participation and expression of views should be actively encouraged. The local and national context (and other contextual factors) should be studied and built upon, to make the model meet those needs and utilize those opportunities that would appear within existing energy policies and activities.

Fifthly, a *modest investment level* was also talked of as an important aspect. This was connected to energy efficiency in the technical design, which was also important in itself. Modest ambitions for the kinds of electricity services to be provided was seen as necessary in terms of choosing those electricity services that give much value for many people for low investment. And finally, it was, as mentioned above, seen as important to create a model/pilot project that could be *possible for others to repeat/replicate*. A hope was that it should be possible to replicate it in large numbers, "scale it up". Replicability was understood as depending on most of the aspects of an energy model, because problems on one key aspect could be enough to make replication difficult. There was an anticipation that a pure commercial model could not be achieved if it was going to provide important services to many people in a place where most of the people are very poor.

These guiding principles remained almost the same underway in the gradual development of the solar power model, although they gradually became more specific and clearly articulated through the discussions on the details of the model. The different goals were also emphasized differently by different team members and other involved people, and this led to vigorous discussions on many aspects of the planned power supply, and a struggle to deal with dilemmas. For example, some participants were more concerned about economic sustainability than others, while some were more concerned about specific social services that would benefit the community, but that might not sustain themselves economically.

The objectives, or guiding principles, can be summarized as shown in the table below. The first column of the table shows the objectives for the socio-technical design (or social organization) of village-level electricity systems. The second column refers to related, broader aspects of the energy systems and their context, including issues of social equity. The same column also mentions various concepts of "sustainability", which are included because such more general concepts are commonly used in the theoretical and empirical literature, as mentioned in Chapter 3.

Table 7. Visions or guiding principles used by the project team, and how they relate to issues of distribution, social equity, and other aspects of sustainability, and contextual factors.

	Desirable qualities of a local electricity system	**General themes of social equity and sustainability**
1	Broad access to the electricity services	Access, equity, gender, economic opportunities (social and political sustainability)
2	Economic viability/sustainability, expandability	Business model/economic design (economic sustainability)
3	Well functioning operations and maintenance	Practical workability, the role of local actors, operational details (organizational/institutional, technical and political sustainability)
4	Gender and context sensitive planning, implementation and operation	Gender equity, embeddedness in context, marginalized groups, poverty, adaptation to national framework conditions (all kinds of "sustainability")
5	Modest investment level	Cost effectiveness, energy efficiency (environmental and economic sustainability)
6	Replicable/scalable system	Likely to depend on most of the other aspects as well as supporting policies and other broader system innovation

The team had some awareness that the fulfillment of such goals was not going to be straightforward. Knowing earlier projects, including the case studied in India, the challenges met had often hindered the achievement of such goals. The team was also aware of potential dilemmas between some of the goals, as found in the Indian case. However, there was much optimism among the team members that the project, given the research based, context sensitive approach, the various experts in the team, and the learning from India, that some of the challenges seen in other projects could be possible to solve.

6.3. Considering various types of places for the project

From the outset, no specific place was selected in Kenya and no criteria or procedures was suggested for how to select a place. The ideas, suggestions and considerations about this came up spontaneously at an early stage of the project, mostly brought up by Kenyan team members. One suggestion was a place in Kitui County – Ikisaya village – where a Kenyan-Norwegian research team had carried out research on vulnerability and adaptation to climate change a few years earlier. Two of the team members and another contact in Kenya had been involved in this research, and they would be interested to do some more work in this geographical area. They found it interesting to do an action research project because people could thereby get something directly back from the project.

Another suggestion was to select two places in Turkana County, Nasigel and Gold. The contact from Kenya Power was interested to work with the team and try out some ideas for solar power supply in these villages. The places were near one of the isolated power grids that he was responsible for, in Lodwar, and he could thus be able to follow up new projects in relation to his flights to Turkana. He could also potentially train the staff at the power station in Lodwar if the village projects would need assistance. These two neighboring villages were small and very poor, and most of the houses were "semi-permanent". If choosing this option, the team could get an opportunity to work closely with the Government of Kenya.

A third suggestion was a place at the coast, Kipini, where two of the team members had been involved in setting up a mini-grid system for the use of bio-diesel produced locally. They suggested to install solar PV panels in addition to the existing small diesel generators in order to provide extra power to meet growing demand from the community members and make up a useful hybrid system where the solar power and the diesel/biodiesel could complement each other. A reason for suggesting this place was also its higher economic activity than in the alternative places, and thereby better ability to sustain a power supply economically. The two latter places had dense settlements – the dwellings were close to each other – which could make a mini-grid model fit there.

The considerations on which place to select raised many important issues around general relations between the working of a local energy project and characteristics of the place where it is located. Criteria for the selection were drafted and circulated for comments. Some of the criteria were self-evident, like interest from the community and sunny conditions (which exist in most of Kenya). A criterion that was influenced by the idea of a mini-grid model was that some of the settlement should be dense enough for this model. Another point was that the project should not be implemented in a place where the electricity grid exists or is likely to be put in place in the next 10 years. Furthermore, although the team aimed to create a model that could work in poor communities, we agreed to avoid the most deprived places for the pilot project. This was because the project could become difficult enough even in a "normal" rural area setting – where the majority of the people are poor and struggle to make a living. Availability of land for the solar panels was also mentioned. Team members expected that the solar power plant was going to be of similar size as the ones seen in India, while it later appeared to become much smaller.

There was need for visiting the places. In the seventh month of the project period, the team leader visited the three places on behalf of the team, accompanied by the Kenya Power representative. Nasigel was a cluster of small houses, a boarding primary school and one shop. Gold was slightly bigger, with 10-20 permanent buildings. The government master plan had identified these villages as suitable for wind- and solar power supply more than for grid extension. Use of firewood for lighting was common here. Challenges noted for these places in Turkana when it comes to doing a pilot project were the extreme poverty in the area and the large losses of livestock that had happened during recent drought periods. There was a chance that the government could possibly pay the investment costs for a project here, but they would then also decide about the design, implementation and organization, and take care of the maintenance. This would be positive, but would limit the usefulness of the project as a research activity.

The village Kipini in the Lamu District and its people looked prosperous compared with Nasigel and Gold. The houses were built back to back, and there were narrow paths between them. A Kenyan team member who had participated in its planning and installation, said that the settlement was so dense that there had hardly been space for installing the poles for the mini-grid between the houses, so a large portion of the houses were connected. A local committee was taking care of the management and operation of the power supply and collected the fees from the customers. Kipini was a relevant place for the project, but the team found it more interesting to start in a place where there was no power supply system in place already and build something up from the start. This was also recommended by an official in Ministry of Energy.

Special challenges noted on the third alternative, Ikisaya, and neighboring villages, were that the people live in scattered settlements outside small market areas or "towns" and that the degree of poverty among the potential users of electricity was large. There was a long drought period, leading to loss of livestock and increased poverty. Moreover, there were challenges that were far beyond the scope of the project: need for improved water supply, better roads, alternative sources of fodder for animals during drought periods, and diversification of income generation.

The team gradually realized that the selection of the place for the pilot project would have strong implications for the working of a solar mini-grid model. However, it was also realized that the overarching question that the team was actually discussing was whether to choose a place that suited the suggested kind of model or rather to choose a place in need for a suitable model. The decision became the latter. The team decided to choose a place that represented a type of village where there is need for figuring out suitable solutions for how the people can get access to electricity. Ikisaya was therefore chosen in the end.

The place has typical features of places in Kenya's arid and semi-arid lands (ASALs), which make up 88% of the land area of Kenya and have around 25% (around ten million) of the country's population. These areas have the lowest level of access to basic services and the highest level of poverty in Kenya (Republic of Kenya 2012b). The population density in these areas is low, from four to nine households per square km on average, making it technically and economically difficult to use a grid approach for electrification. The village Ikisaya was seen as representative for such areas in Kenya. The village probably also has similarities with many villages in other countries in Sub-Saharan Africa. Villages with dispersed settlement patterns are common and represent a large challenge for rural electrification in Sub-Saharan countries (Karekezi 2002).

The selection of this specific village among others in the same area was also influenced by its placement outside the Rural Electrification Master Plan for future electrification in Kenya. The team had briefly considered Endau town, a neighboring village south of Ikisaya, but it was found to be inside the long-term plans for grid extension, while Ikisaya was outside. Endau was also considered to be too big for what the team could be able to do in terms of investment cost. A member of the team had grown up in Ikisaya and could facilitate close cooperation with the village administration and community members. This was seen as an advantage, because it was uncertain who could be the "local partner" for the project.

6.4. The inspiration from India

The visit in India was viewed with much excitement by the participants before, during and after. An excursion and workshop, "Solar Learning"[52], was organized in parallel with the case study as mentioned earlier. This gave an opportunity for the project members to interact with invited guests from outside of the team, both from Kenya, India and Norway. On the bus from Kolkata towards the ferry to the Sunderban Islands, there was vigorous exchange of information and ideas on solar PV technology and rural electrification, although many of the participants had just met for the first time. The project team members had met for the second time, five months after the meeting in Oslo, and were eager to find out what could be learned for the task ahead in Kenya.

From Kenya, five persons attended in addition to the five Kenyan team members: The contact from Kenya Power, a government official from Kitui County (drought management officer), a project installer, a solar battery producer, and a coordinator of a solar energy association. The initial plan had also been to invite people from a village in Kenya, but it became difficult at this early stage. The visit took place towards the end of the process of selecting a place in Kenya. During the stay in India there were conversations on the coming work in Kenya both within the team and with other participants. Specific challenges were discussed, for example how to avoid payment problems and battery problems. New types of electricity meters for mini-grids were mentioned by WBREDA, and alternative arrangements for collection of payment from the customers were discussed.

6.4.1. Early "spin-off" projects in Kenya

Most of the team members had not seen solar mini-grids before, and not this size of solar PV installations (up to 110 kW). This in itself was inspiring, although the problems of these impressive solar power plants also became clear. In hindsight the team learned just as much from the problems as from the well-working features, but during the first days the excitement was strong. "Seeing is believing", according to the participant from the Kenyan government.

[52] Supported by the Research Council of Norway's GLOBMEK program

The abovementioned government contact was the one who acted fastest after the trip and surprised the team by initiating some immediate work in Kenya inspired by the information obtained in India. Right after the visit, he wrote a report to the Ministry of Energy where he explained the technical details of the solar PV-systems that he had seen in India, and included pictures of the panels, batteries and "power conditioning units" (charging regulators and inverters). He had earlier suggested to the Ministry of Energy that he would be interested to try out solar PV in one of the government's remote, isolated diesel power grids. He was looking for a way of saving fuel costs. The Permanent Secretary of the Ministry of Energy had previously not been supportive of the plans, but the report from India with pictures of large solar PV installations convinced him, according to our contact, that it could be feasible to combine the use of solar PV panels with power generation by the diesel generators. This was a different use of solar PV than had been observed in India, but the Indian solar mini-grids gave some relevant information and demonstration.

During the first three years after the visit in India, this work continued, and the Government of Kenya added solar PV capacity in five isolated power grids (first Merti, then Habaswein, Hola, Elwak and Lodwar) as a complement to the large diesel generators that were already there. These immediate quick and unexpected effects of the project inspired the team during the whole project, while working to develop the local project in Ikisaya village which started operating two years later. These immediate effects in Kenya were not created by this single event alone, though, it was most likely also facilitated by the general development in the solar PV field, nationally and internationally, including existing suppliers who could install larger systems, increasing use of solar PV worldwide, and ongoing price-drops.

In addition to the understanding of the Sunderban solar mini-grids, which were studied in depth, the Indian team member provided a glimpse into a different model. The team was invited and recommended to see two small solar charging stations that were part of their large activity in India for provision of light for households (Lighting a Billion Lives, LaBL). These charging stations consisted of a building owned by an organization or a private person, a solar panel on the roof, junction boxes (charging boxes) mounted on the wall inside the house and a number of portable lanterns that were plugged in for charging. The lanterns were rented out to people, who would then carry them home and use them in the evening and night, and thereafter come back on the next day to deliver them for charging. People paid a fee for the renting and the operator got some payment for the job. NGOs acted as intermediates between the implementing agency and the local charging stations.

Based on this observation, the same government person and two other participants from Kenya developed plans for a small charging station in Kenya, spontaneously, during the trip. This would be implemented in one of the two villages that he had suggested for the Solar Transitions project, Nasigel. His two partners for this project were a Kenyan team member who was both a solar business person (selling solar lanterns and solar home systems) and energy researcher, and a renewable energy expert (technical expert and importer and installer of power stations) in Kenya. They figured out how they could construct a small solar charging station for renting of portable lanterns with equipment that was already available in the Kenyan market: small solar LED lanterns with separate solar panels. They would mount all the small solar panels that belonged to the lanterns together in rows in a tailor made metal rack so that the lanterns could be connected and charged in one place, at a school, and rented out at a low price to school children and their families. The three people said they wanted to act faster than the plan was for the Solar Transitions project. Nasigel "charging kiosk" was implemented six months later, with much excitement and a newspaper piece because Kenya Power contributed funds for this activity from their Corporate Social Responsibility (CSR) budget.

6.4.2. The use of research findings and lessons learned in India

Sessions for sharing of research findings on the Indian case study were organized in project meetings, and results of the case study were distributed among team members by email, after some of the team members had written about them. The Indian experiences were also repeatedly referred to by team members in discussions about the Kenyan model, both during and long after the stay in India.

Different team members brought along and emphasized different aspects of the mini-grid systems studied in the Sunderban Islands. Some showed concern about the challenges in reaching all community members, and the electricity customers' need for some flexibility in how and when to use the electricity. Others showed more concern for the importance of the local operators and their motivation, or the challenges of building up an organizational framework for the management, operation, and maintenance of the systems.

A session of a team meeting in Nairobi in October 2010 was devoted to reflections on what had been learned from India both through the case study research and observations by team members who had participated in the study tour only. Several of the team members mentioned that they were impressed by the willingness of WBREDA to share all their experiences, also the problems they had faced, and this was found to be positive for the team's work in Kenya. Another comment was that it is important to influence the government in Kenya to support such energy supply, like the Indian Government does. A lesson learned by team members was also that it is important to create flexibility in the use of electricity. In a power system with a limited amount of power available, it is important to focus on avoiding over-consumption and payment failure from the customers, some argued. Others added that it is equally important to facilitate increased use of electricity when people gradually find out how they can use it and benefit from it.

The idea of using portable, chargeable lamps was mentioned as very interesting, and it was discussed whether school children could carry the lamps since the parents would not have time to go every day to charge the lamp. One of the team members said that women should be involved in the collection of tariffs since they tend to be more honest. Another team member pointed out that there are big differences between Sunderban and Ikisaya so that "we have to think for ourselves as much as transferring ideas and knowledge from India". This seemed to be a common view in the team, and the ideas for the power supply in Ikisaya did move away from the model studied in the Sunderban, but only gradually. In addition to these points, many of those research findings presented on the Indian case study in Chapter 5 seemed to be shared by several team members.

6.5. Concluding remarks

The chapter has presented the first part of an activity to embed a practical pilot project in the context of ongoing efforts within provision of electricity through decentralized energy models in Kenya. In combination with Chapter 5 on the Indian case, the chapter has shown early phases of a planned strategy for transfer of innovations between places and countries. These chapters, together with the next two chapters have relevance for the concept of inter-local learning as described by Coenen et al. (2010) and Geels and Raven (2006), and for spatial transfer of innovations, including international knowledge sharing. While the previous chapter demonstrated a way in which the examples can be understood, this chapter has explained some of the foundations for a learning process in the context were the involved actors intend to use the examples as inputs, including the differences between the national framework conditions in the two countries involved.

Chapter 7: The Kenyan case (II): The development of a "socio-technical design"

This chapter continues the analysis of the Kenyan case by describing and discussing the process of developing a socio-technical design for a pilot project in Kenya, based on the study of solar mini-grids in India. Chapter 6 explained the way the process was connected to the existing work on solar power and other renewable energy in Kenya, and how a specific village for the pilot project was selected. This chapter describes and discusses the kinds of factors that influenced the socio-technical design of the Ikisaya energy model and its differences with the Sunderban example. These were both the societal context at different geographical levels, local people's suggestions and the ways in which these were taken into account by the project team, as well as other considerations, interests and limits. The action research in the Kenyan case made it possible to describe the way in which the socio-technical design gradually came into being and the reasons for the shape it took, while in the Indian case, the design process could only be studied in hindsight. The guiding question for this part of the action research and socio-technical design process was simply "what kind of village-level solar electricity provision is suitable for Ikisaya village and other villages in poor, remote areas?"

The development of the socio-technical design as well as the implementation process can be seen as representing early phases of a socio-technical experiment, before the start of operation (dimension C of the case study framework). The chapter shows how a socio-technical design for a seemingly simple system for electricity provision may be configured by a range of social and technical elements and how a range of factors may influence its design. This theme is related to the underlying theoretical question of how learning and innovation processes are facilitated and stimulated in socio-technical experimentation, and how learning between geographical contexts as well as social science contributions may contribute to such learning processes.

The chapter consists of six parts. First, a description of the selected village shows the kind of understanding of the local, socio-cultural context that influenced the socio-technical design, implementation process, and the further improvement of the energy model. The second part describes the first ideas for the socio-technical design, which were later found to be unsuitable, and the third part describes the cooperation between the project team and the village community, showing how the ideas gradually emerged. The fourth part shows the considerations on how the model could be designed in order to fulfil the suggestions from the community members as well as the guiding goals (affordability, economic sustainability, etc.). The fifth part describes the start-up phase of the village energy project and the sixth and last part provides an overview of the main changes done on the way from the Indian to the

Kenyan model and discusses their reasons.

7.1. Description of Ikisaya village: The local, socio-cultural context for the project

A description of the village where the electricity project was developed and implemented is important in order to understand the process of socio-technical change that took place (dimension B of the case study framework). The team's understanding of Ikisaya, the village selected for the pilot project, played an important role for how the solar power model was designed and also for the way it changed after start-up. For an outsider to a community with the kinds of extreme and complex challenges that characterize Kenya's arid and semi-arid lands, it is probably not possible to fully comprehend people's situation. However, in addition to the understanding achieved through the initial research, a gradually deeper understanding was obtained through applying the research findings in practice through cooperation with the community over several years.

Ikisaya is a small, remote village located in Kitui County in the Eastern Province of Kenya, near Endau Hill. The distance from Nairobi is 250 km eastwards, and the travel time by car from Nairobi to Ikisaya is 6-7 hours. The population in Ikisaya is 283 households, 1.634 people.[53] The homes are far from the roads and hidden by bush. Figure 11 below shows Ikisaya, or Syou sub-location, and five other villages in the area, which will be mentioned in Chapter 8. The market area in Ikisaya includes 10-12 shops and offices and a number of small kiosks (where people sell tea, chapatti, fruit, etc.), the Ikisaya primary school and the main water point. Administratively, Ikisaya is a sub-location in Malalani location and the sub-chief is the administrative leader.

[53] The total number of households in the whole of Malalani location is 1270 (Republic of Kenya 2010).

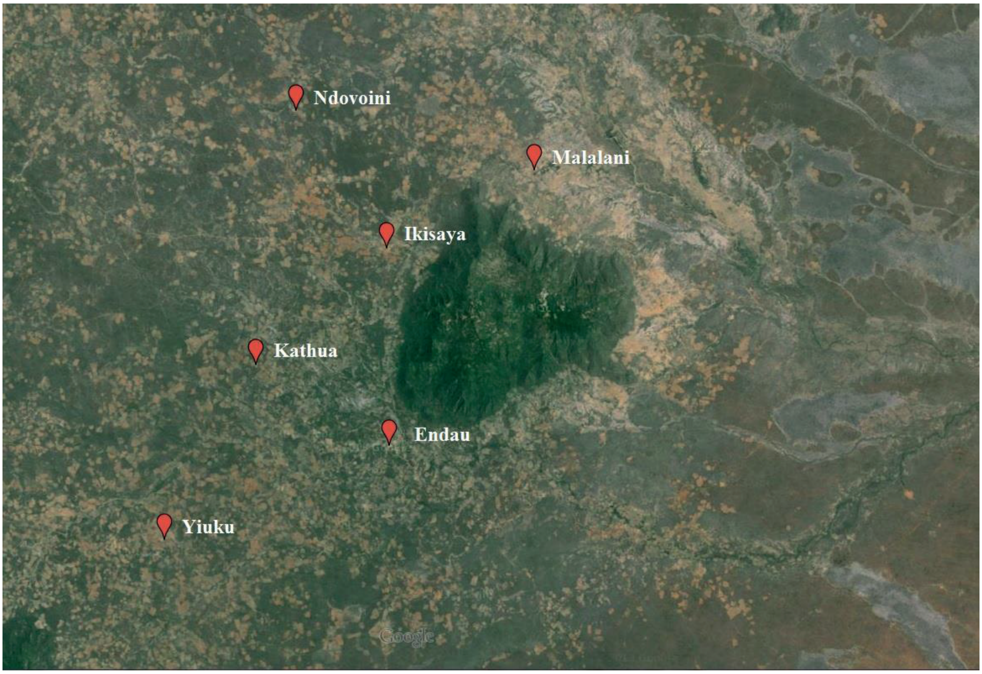

Figure 11. Map of Ikisaya and surrounding area. The Endau Hill can be seen in the middle of the map, and the gray spots are farms. Source: Google Earth.

7.1.1. Economic activities and livelihoods in Ikisaya

The majority of the inhabitants in Ikisaya are agro-pastoralists, as in most of the rural areas of Kitui County. Subsistence farming, livestock keeping and charcoal production are the main sources of livelihoods. The climate is hot and the rates of evaporation are high. The people in Ikisaya rely on the two annual seasons for their rain-fed agriculture. The crops that are commonly grown are green grams, cow peas, sorghum, millet and maize. The population is highly dependent on the land, the animals, the rainy seasons and sufficient time and ability to work on the land, graze and water the animals, invest in seeds and livestock and utilize other natural resources. The ownership of farm land and livestock is highly unequal between the community members. As a result of frequent droughts, agriculture is often insufficient to sustain a living. The rate of crop failure is as high as for the rest of the semi-arid and arid eastern Kenya. For instance, in 2010 and 2011, the area experienced four successive growing seasons that failed due to short or lacking rainy seasons, resulting in 80-90% crop failure in the driest areas and 50-60% in the less dry areas of Eastern Kenya (Recha et al. 2012). In Ikisaya, several rainy seasons failed or partly failed during the period from October 2010 until February 2014. Moreover, heavy downpours and flooding are common during the rainy season, and these also sometimes damage crops and property as well as roads. Food aid is sometimes provided, but the aid is normally only enough for a few extra days of food consumption.

Cash income is difficult to obtain in the area. Of the population in Kitui County (1,012,709 people)[54] a portion of 63,5% was estimated to live below the poverty line in 2005/2006.[55] This is rank 35 out of Kenya's 47 counties. A range of problems occur because of lack of money, including difficulties to purchase enough food for the family and pay school fees for the children, especially at the secondary school level. In Ikisaya, only a small number of people have a regular, stable income, and very few jobs are available. Only the teachers and the local administration have a formal employment, and only 10-12 other people have shops or other small businesses that give income around the year. Most of the population depends on agriculture, casual work for larger farmers, remittances from relatives and a diversity of other strategies for obtaining income and food.

People are actively maneuvering in a struggle for coping with a difficult situation. Within a narrow space they are trying to utilize the very few options available to cope with or escape from a situation of poverty and vulnerability. One strategy for securing material means for survival is to form relations among individuals, politicians, customary institutions, and government administration. This is also a strategy for influencing collective decision making (Eriksen and Lind 2009). Various livelihood groups exist, such as goat groups, farming groups and a soap production group. Some of these have been started by NGOs, while others have been started by community members.

7.1.2. Dealing with lack of infrastructure

A typical feature of villages in Kenya's arid and semi-arid lands, in addition to the high level of poverty and vulnerability, is the low level of access to basic services, such as access to clean water, roads, public transport, education, health facilities and access to energy (Republic of Kenya 2012a). For example, many people in Ikisaya as well as in surrounding villages walk very long distances in order to fetch water – up to 6-8 km each way. After arriving at the water point near Ikisaya, there is often several hours to wait in a queue before getting water, which is tapped into plastic cans one by one from a small tap. Fetching water is mostly done by women. For many of them, almost a whole day is spent on fetching water, normally done every second day. This reduces the time available for all the other responsibilities of the women. During the rains, water is collected and stored by those who can afford to invest in tanks and barrels, and in earth or sand dams dug with support from the government at the county level. A pipeline from Endau Hill was installed in the 1970's by an NGO, and the community has managed to sustain this infrastructure since that time, while similar installations in neighboring villages have broken down.

The water supply in the village demonstrates community organization of local infrastructure. A committee appointed by the sub-chief manages the water supply through monthly meetings. A water attendant is employed in order to take care of the delivery of water, which is often rationed during the long dry seasons. He or she also collects the payment for the water. The price for the water was 2 Ksh per 20 liter plastic can in 2014. The salary for the water attendant is paid from the revenue generated, while the rest is used for

[54] Kenya Population Census data 2009 (Republic of Kenya 2010)
[55] Kenya County Fact Sheets, Commission on Revenue Allocation 2011

sitting allowances for the water committee and saved for maintenance of the pipeline to stop leaks of water. It is difficult to raise enough money for larger maintenance such as replacement of the old pipes.

Ikisaya sub-location has two public primary schools[56] – Ikisaya and Ndovoini, 10 km apart. At the time of the survey in 2010, they had a combined total enrolment of about 500; 70% of the boys in the sub location and 60% of the girls. As with adult literacy, enrolment at the primary school level is skewed in favor of males in Ikisaya. The nearest secondary schools are in Endau and Malalani, 9-10 km away. Primary education is free in public schools. This means that there are no statutory fees that parents are required to pay, but the parents have to pay some contributions towards specific projects in the schools. There is no health clinic in Ikisaya, only 10 km southwards (in Endau town).

Most of the mobility in Ikisaya and between villages is walking. It is common for children to walk 6-8 km to reach school. Donkeys are used for carrying water and goods. It is possible to hire a lift with people who have a motorbike, but this is expensive. Nobody in Ikisaya owns a car (as per January 2014). There is no public transport that connects different parts of the sub-location, and there is little public transport to other villages or towns. The only bus leaves at 3:30 a.m. for Kitui, arriving at 7 a.m. and returning to Ikisaya in the late evening. The road standard from Ikisaya to Kitui is very poor.

Kitui is a town with 109,568 inhabitants[57], located 90 km away, which has larger hospitals and medical expertise, various banks and modern shops selling IT-equipment and accessories, like toner for photocopy machines. Later, this appeared to be important for the project in Ikisaya. The bus drivers often bring goods and parcels for people and drop them at the various bus stops. Communication through mobile phone and financial transactions by M-pesa[58] help carry out important errands. However, the poor phone network in the area is a problem, and many people have to walk far even to make a phone call.

7.1.3. Energy use relevant for electricity provision in Ikisaya

Small amounts of electricity were used in Ikisaya before the solar project was implemented, as shown by the survey carried out in 2010. Some phone charging was provided by small businesses using small solar PV systems. About half of the families were found to own a mobile phone. The average expenditure on phone charging was 115 Ksh per month (1 €), according to the household survey. The portion of survey respondents reporting that they use kerosene for lighting was 92%. Torches and radios run on dry cell batteries were also widespread, used by 93%. A solar home system (described in Chapter 1) was used by, but not necessarily owned by, 6%.

The survey showed an average lighting expenditure, i.e. expenditure on kerosene and dry cell batteries of 350 Ksh per month (3 €), (11.66 Ksh per day). There were large differences between the households. 40 of the 73 household spent less than average, and the

---

[56] 40% of respondents to the survey conducted in 2010 - both male and female – reported to have no formal education. The number of respondents were 70.

[57] Population Census data 2009 (Republic of Kenya 2010).

[58] M-Pesa means mobile money, and is a system for doing cash transfer and banking through mobile phones.

median expenditure was 160 Ksh (5.30 Ksh per day), meaning that 50% of the respondents spent this amount or less. Some people used no other means of light than firewood, because kerosene or other alternatives were not affordable to them, and some used very small amounts of kerosene. Studies elsewhere in Kenya had earlier indicated that it was normal to spend around 10 Ksh per day per family on kerosene, according to team members, but in Ikisaya, most of the households spent less. Data from a comprehensive survey in Kenya in 2005/06[59] shows that median household expenditure on lighting was 191 Ksh per month (6.5 Ksh per day). Of this, the kerosene portion was 156 Ksh and the portion for dry cell batteries for torches was 35 Ksh.

7.2. The first ideas for the socio-technical design

There is a wide range of possible new combinations to organize off-grid electricity supply, socially and technologically, as has been observed in off-grid electricity supply in general, and exemplified by the Sunderban model. A village-level solar PV system, and even a specific kind of model such as solar mimi-grid model can be designed in many different ways.

7.2.1. Early ideas about adaptation of the Indian mini-grid model

An early and preliminary attempt to design a power supply system suitable for the Ikisaya kind of village was made in October 2010, before the main part of the interaction with the community had taken place. The suggested design was composed quickly, because of a deadline for proposals for funding technical equipment. This first draft design shows which ideas the team was able to come up with at that point in time, and how the idea of a kind of a solar mini-grid was combined with ideas on how to complement it with other solutions due to those contextual differences between the Sunderban villages and Ikisaya that were known at that point in time.

A small grid was suggested to cover the market area centrally in the village and those few households located within the reach of such a grid, around a 2 km radius. The market area included the Ikisaya primary school, the local administration and 10-12 small shops and kiosks. A 12 kW solar system, around half the size of the smallest systems seen in the Sunderban (but ten times larger than the final design that was chosen in the end) was suggested for this area. For the rest of the village, other solutions were considered. This solar power plant would also supply power for charging of portable lanterns, portable batteries and mobile phones. The batteries would be carried back and forth for charging and plugged in at home to give power for light, phone charging and radio. For the cheaper option of lantern charging, people would rent charged, portable lamps at the power plant and use them at home for a couple of days, and then carry them back for charging. The idea of portable lights was clearly inspired by the lantern charging system observed in India. The idea of portable batteries was suggested by Kenyan team members based on the widespread business of

[59] Lighting Africa 2012, Household Lighting Fuel Costs in Kenya. Market Intelligence Note, Issue 2, Dec. 2012, Based on The Kenya intergrated Household budget Survey (KIHBS) carried out by the Kenya National Bureau of Statistics in 2005/06

charging batteries in grid-connected areas in Kenya, for people who are not able to connect to the grid.

There was significant uncertainty among the team members on how the proposed solutions could work. For instance, there was uncertainty on how people could carry the batteries and lanterns back and forth for charging, and whether people could combine it with fetching water. There was also uncertainty about what people could afford and which other services than light and mobile charging would be relevant. A question was whether income generating activities would be possible, and which ones.

Complementary to the mini-grid and charging approach, the team touched upon an idea of providing solar home systems as a solution for households outside a local grid. However, this was not seen as an option, because it would require investment support to individual households. Very few households could afford to purchase them at a market price, even if paying over a long time. The team agreed not to develop a model where solar home systems would be subsidized, because this could distort the market for solar home systems in Kenya and hinder replication of the project by the government.

7.2.2. The need for revising the vision of implementing a solar mini-grid

As part of the pondering of solutions that could work in Ikisaya, the team tried to get an impression of the distances from the center of the village to each of the households. It was clear that the households were widely spread, but it was far from clear where they actually were. Two assistants were therefore employed in Ikisaya to collect the GPS points for all the 283 households in the village.

The resulting map (Figure 12 below) showed that the settlement was even more dispersed than assumed. Each dot on the map represents a household, except for 15-20 dots around the Ikisaya market (at the road junction) which are representing offices, churches, shops, small kiosks and schools. Most of the homes are scattered over an area of more than 40 km^2, giving an average of around 10 households per square kilometer within that area.

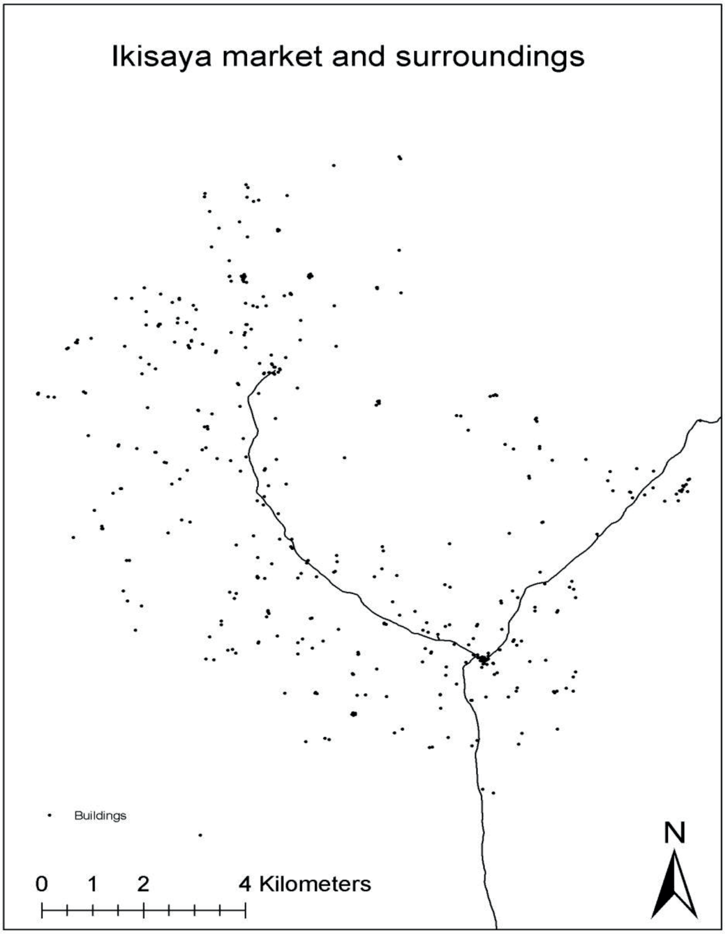

Figure 12. Map showing all the households and market buildings in Ikisaya.[60]

When seeing this map, the team started to fully realize the challenge of such settlement patterns for providing electricity access for the people here and in many other places within Sub-Saharan Africa (and possibly elsewhere), and that conventional grid extension faces a serious shortcoming for reaching the households in such areas. This information also confirmed the large differences between this geographic context and the densely populated communities visited in the Sunderban Islands.

As mentioned by Smith et al. (2005), it is sometimes necessary to revise the visions for socio-technical change based on specific circumstances and renegotiations and the process of transformation itself. The realities of the geographical area in combination with other reasons mentioned further below, forced the team to abandon the mini-grid vision completely.

[60] Made by Winnie Mulli, David Mutava, Ragnhild Vognild and Kirsten Ulsrud.

However, the necessity of doing so was realized only gradually, and the team worked on two parallel plans for some months. Apart from the plan for a mini-grid type of model, a smaller kind of project was considered. The emails and the minutes from meetings show that the discussions switched between these plans and created confusion and some frustration in the team. It was disappointing for some of the team members to abandon the mini-grid model which had been such a strong vision since the project started. A disappointment for some was that the smaller project could only provide power for small and basic uses of electricity, and not for larger uses that could possibly have contributed to some kind of production and value added to local economic activities, although it appeared to be problematic to define what this could actually have been, as shown below. The team started to concentrate fully on a smaller kind of project.

7.3. Interaction between the implementing team and potential users of electricity

This section describes the interaction between the project team and the community members in Ikisaya as part of the action research for planning of the electricity provision. This was a strategy for taking the users' or rather potential users' views and knowledge into account during the socio-technical design process, and thereby facilitate co-generation of knowledge between participants with academic knowledge, practitioners' expertise and those who have knowledge of a local community and a particular geographical area.

The cooperation with Ikisaya was established in 2010, initially by communication through a person who had grown up in the village, who gradually became a part of the team. The project team thereafter visited the village in late 2010 in order to provide information about the project and discuss the potential cooperation. The village leaders and other community members stated their interest in the project and its basic ideas. They showed interest in utilizing solar resources in a way that could benefit the whole community. An educated woman among the village leaders gave the following remark in one of the meetings in Ikisaya: "Thank you for showing us that the sunshine can be utilized, and we have long hours of sunshine. Sometimes we think that we are in the wrong part of the country, but now we see that we have something that can be used. So we support the project."

Four team visits were made to Ikisaya during the planning phase: in March, October and November 2011 and in January-February 2012. The energy systems started operating in March 2012. Important visits and errands were also done by an individual team member. The team gave information at different government levels, including the Chief[61] in the location (Malalani), the District Authorities and the county level unit of the Ministry of Arid and Semi-Arid Lands. These government officials were supportive and confirmed their acceptance of the project.[62]

Before the first meetings in the village, the team had discussed who would be suitable actors or organizations to own and operate power plants in remote villages. Could the

[61] The governmental, admimnistrative leader at the level of the location
[62] Letters of support from district and county offices were obtained.

government take responsibility for it, could an NGO do it, could private companies participate or could the local community do it on their own, based on some sort of "start package" of advice, investment support, training and follow up? A solution was suggested by the community leaders on their own initiative: "We want to start a CBO (Community Based Organization)[63] that can own and operate the power supply as a business, and we want to use the surplus for expansion of the system and general improvements in the village". This was the first decision on what the socio-technical design of the power supply model would look like, except for the choice of solar PV technology at the village level.

7.3.1. Overview of the planning process with the community

The timeline below shows the main steps in the cooperation with Ikisaya village. Steps 1-9 are described in this chapter, and step 10-11 are described in the next chapter. The steps described in this chapter were taken partly in parallel. The most important part of the planning of the details of the Kenyan pilot project took place during the year 2011, while the project started operating in March 2012.

Activity #	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Specific activities	Formal letter to village, incl. district authorities, initial meetings	Research: Mapping needs and challenges	Meetings: Prioritizing services, defining org. model, by-laws, procedure for hiring staff	Formation of CBO	Initial system design
Timing	2010	2011	2011	2011	2011

Activity 6	Activity 7	Activity 8	Activity 9	Activity 10	Activity 11
System design presented and adjusted	Procurement	Jobs announced, staff hired	Installation, training, operation, information	Follow-up visits and phone calls	Adjustments, improvements
2011	2011-12	2011	2012	2012-	2012-

Figure 13. Timeline showing the steps in the cooperation with the Ikisaya community.

7.3.2. The ways of interacting with the potential users

Community members were consulted by the team at different times during the planning process and their views were sought in different ways, including different social science

[63] CBOs are a common aproach to organizing members of a community through registration as self-help groups by the District office of the Department of Culture and Social Services administratively under the Ministry of Home Affairs, Culture and Social Services. CBOs have a constitution/by-laws which detail their objectives and their operational and governance structures (Muchunku et al. 2014).

methods. Meetings were also held with the sub-chief, the village leaders' group, the school committee, the water committee and the wider public. The organization of the water supply would have relevance for how to organize the power supply. The purposes of the meetings in Ikisaya were to update the community members on the progress of the team's work, provide as much information about the project as possible, and based on that, receive comments, answer questions, receive relevant information and suggestions, discuss solutions and make plans. The communication was translated between English and Kikamba language, except for some smaller meetings where all participants spoke English. After every visit and research activity in the community the team went back to internal discussions on how to design the energy model. Letters and messages were sent to the village leaders in order to give updates on the progress of the funding work and other preparations. Public meetings were held in Ikisaya several times during the period up to start-up.

The team used social science research methods, especially qualitative interviews and group interviews, in order to get the views of people who might not attend the public meetings or people who might not give their views in the meetings. Some could feel uncomfortable to speak in public meetings, perhaps due to a feeling of lower status than others – for example because of low education or poor economy. There was also a risk that some would keep quiet because they would feel it difficult to oppose the views of powerful people in the village whom they might depend on economically. Women tended to be reluctant to give their views in the public meetings, except for a few women with higher education. When the team encouraged participation, some of the women gave their suggestions in the meetings. Some women commented to a master student two and a half year later that they had appreciated that the team "insisted" on hearing their views. 20-60 persons attended the public meetings every time. An important purpose of the social science research was to capture the perspectives and views of the poorest and most marginalized people and represent these people in discussions with more influential people in the village, or in discussions internally in the team.

There were also opportunities for people to speak with team members in informal settings: such as tea-shops, in the market area and at the compound of the planned power plant. The team organized a day of public work where people were invited to join team members to do some clearing of the compound of the power plant. 20-30 women and men from the community participated. The trust from the community members seemed to be strengthened by such practical cooperation (commenting humoristically that "this mzungu[64] can dig in the soil"), and by the sub-chief and other local elites' participation.

The framing of the communication with the community members was influenced by the ideas seen as possible by the project team. About one year after the research in India and one year before the provision of electricity services started in Ikisaya, the team's planning of the pilot project in Kenya reached a stage where it was possible to involve the community members in specific discussions on the details of the solar power supply. This was important in order to get realistic discussions on which electricity services should be prioritized and how these could be organized.

[64] A mzungu means a white person in Kiswahili language.

The idea of a solar mini-grid had been mentioned briefly during earlier stages when the team believed that this could be possible to implement. This created certain expectations. However, community members later expressed understanding when the team explained that it was necessary to find other solutions. Some community members said they are used to starting small things and do little by little, like they did when constructing the primary school. Some expressed a strong wish to have an electricity line to their house. The team had started to consider the idea of making an "energy centre" and presented this idea for the community members. With an energy centre, team members said, all the power capacity would be put in one place in the village, so as to make operation easier and get as much as possible out of limited resources. Such a small power station could be a place where one could go and buy electricity – either to use it there through appliances owned by the power plant or to take away as with charged lanterns or other devices, in order to use at home or in a business. The team pointed out that these were just ideas, and that the design would be decided in cooperation with them.

The team informed the community that it would probably be possible to build a solar power supply system of a certain size, 3 kW, within the constraints of the funding. The size was explained by comparing it with a solar panel of 35 W used at one of the shops in the market area. The size would be almost 100 times this size, which would be a relatively small village level solar system, but it could still be useful for the community. The team encouraged conversations on the kinds of appliances and electricity uses or services that could be possible within this size limit, mentioning for example that an iron has a too big consumption, and that big machines would not be possible to use. Water pumping could also not be part of the system. A starting point for the planning could be to think about what electricity may replace, for instance use of kerosene. The team mentioned difficulties experienced elsewhere, like problems of payment and use of high consuming lamps instead of low consuming ones. Another point made by the team was that people may have different interests, for example, men and women, that should be taken into account during the planning.

Our contact in the Kenyan power utility sometimes participated in the meetings, and people asked him why the area is not prioritized for extension of the national electricity grid. He answered that it is not they but REA (Rural Electrification Authority) which is responsible for rural electrification, and that the constituency level is prioritized. He also said that even though the grid would have come to the village, extension of the line to individual buildings would be very expensive, but that it could be done if people paid for that. He also said that the grid had moved closer, since it had reached Zombe (50 km away).

7.3.3. Electricity services suggested by community members

The most important public meeting during the planning process (in March 2011) had 48 participants, almost as many women as men. All participants were invited to mention one thing which they thought of when they heard the word electricity, and all the participants spoke, one after the other, the women first and then the men. Light was described as very important, especially by the women, and sometimes in poetic ways:[65] "Light opens up people's thinking. Light has not been seen here before. Light makes it possible to work at any time. Light opens up everything and makes it possible to see the hidden. Light gives security by driving away dangerous animals. Power is new life – power is life and light. The best with electricity is that we can see at night. Light helps to come out of darkness. Light can be used in dispensary at night and for work during the night. Some work cannot wait – one has to process farm produce quickly. Electric lamps can save kerosene costs, sometimes we cannot afford kerosene". The use of electric light during child birth at night was also mentioned. One of the participants said that women need light the most because they wake up early and go to sleep late at night. Large interest was shown for a portable, electric lantern that was displayed.

There was negotiation on how many lanterns might be needed in Ikisaya and after inputs from the sub-chief it was decided to start with 120 lanterns and add more according to demand. The sub-chief wished that all housholds in Ikisaya could eventually be able to use the lanterns (283 households). Some people expressed interest in the option of owning their own lamp too, instead of renting. One man wanted to rent a battery for offering TV services for the community.

In one meeting the leaders' group said that institutions (i.e. schools) should have the highest priority in the project, then the market area and thereafter the households. The sub-chief, the school headmaster, local leaders and other people mentioned the need to expose the children in Ikisaya to the outside world through TV and internet. The headmaster said it should be possible to introduce computer use for the pupils even with very few computers, and that some of the recently trained teachers are trained in ICT. The need for light for evening "preps" at school for the students before exams was also mentioned. A long-term vision was that if there would be electricity they could manage to start a secondary school in Ikisaya. The headmaster hoped that a next step in the project could make it possible to stretch a power line to the school so that they could use TV in one room and have light installed in the classrooms.

A photo-copying machine was seen as very important by community members since it could save time and costs through avoided travel to other places. Some people also mentioned a computer and printer. The sub-chief mentioned that he would like to try to buy a computer and the headmaster asked if there would be opportunities to charge a computer at the power centre. Regarding phone charging, some people commented that it was sometimes a problem to get the mobile phone charged, because of queues at the existing charging businesses. The power also tended to go out quickly from the phones, sometimes due to poor charging.

Several other ideas were put forward, many of which were later found to be unfeasible by the project team. A suggestion by some community members was to have a fridge for veterinary medicine and vaccines in the village. Snake bites was pointed out as a serious problem that required better and quicker access to the right medicine for people as well as animals. There was also a hope that the availability of some electricity in Ikisaya would make

[65] The quotes are according to notes based on the translation from Kikamba to English language. Quotes from different meeting participants are here combined in one paragraph of quotes.

it possible to get better health service there, which could provide maternity assistance. There was also interest for a blender for production of cosmetic products with aloe vera, in a group that worked on soap making. The team explained that power for such equipment might be outside the scope of the small power centre, but nevertheless kept the suggestions in mind. Some wishes for use of electricity that would be difficult or impossible to fulfill, were such as starting an ironing business, store the milk from the cows and food in fridges in the households, use an electric cooker, or do welding. Such electricity uses could have been done through a conventional grid connection, for those people who could manage to pay for it.

Rivalization between different interests in the selection of electricity services was not experienced. The team informed the community members that their inputs and the research findings on the way of life in Ikisaya would be built upon when the team would come up with a suggestion for the power supply and present it in the village to recieve their views.

7.4. Considerations during the socio-technical design process

The main considerations in the team on the details of the socio-technical design were going on between the visits in Ikisaya over a long time, and through emails and meetings. Which electricity uses (services) could be provided and how? What should the electricity model look like in order to meet the needs of this community and similar communities as this? How much would it cost and how could it be financed?

7.4.1. The room for maneuver for the involved actors

As mentioned in Chapter 2, actors develop socio-technical designs within certain boundaries or limitations, providing a certain room for maneuver. The opportunities to compose and combine social and technical elements are partly defined by various factors outside the actors' control – factors that they *have to* take into account (social structures that constrain the actors). In this case, such factors were the basic characteristics of the available solar PV technology, its costs, available funds, the settlement pattern in the village, and other aspects of the local context. Partly, the room for maneuver for the actors is defined by factors they can *choose* to take into account. In this case these included some of the policy trends within electricity and renewable energy at the national level in Kenya. The actors could also choose to what extent they were willing to adapt the system to the local context. Some of the opportunities and restrictions kept changing underway, such as the availability of good quality, portable and chargeable lanterns in Kenya.

One of the factors that had to be dealt with was uncertainty of the financing of investments in technical equipment. This uncertainty had an impact on the planning of the Ikisaya project by making the planning process last longer and by increasing the uncertainty for the team on what would be possible to do. The team had received a research grant for work time, travel and meetings, but the financing for technical equipment was not in place from the outset.[66]

In the end, the team was able to raise funds, but smaller than expected. A positive consequence of the funding struggle for the Kenyan pilot project was that many ideas were thought through and discussed during work on a number of funding proposals. It appeared later that this helped to push the team towards a better solution for Ikisaya than a solar mini-grid would have been. The team was free to make changes in the socio-technical design throughout the project, both before and after implementation in Ikisaya. There was large freedom to do things in new ways and try out new combinations, which is what innovation is about (Fagerberg 2005). This was later found to be crucial for the changes made after implementation.

The ideas for the socio-technical design for the Ikisaya project continued to change based on new information available, barriers and opportunities discovered along the way, funding constraints, research results, and negotiations between team members. Those team members who were most active and participated in most of the meetings and communication had a larger impact on the outcomes than those that were less active and less present. The involvement of the team members depended both on their worktime within the research grant, kinds of skills and their ways of doing their work, and their personal engagement and commitment. The different team members' influence on the work varied underway, especially in the sense that the practitioners' roles became stronger closer to practical implementation. The activity became dependent on their expertise at that time, although others' work was also needed.

The observations in India were referred to in project team meetings; "as we saw in India it is important to avoid overuse of power", for instance. In addition, team members also once in a while referred to other projects they had been involved in or studied. The design considerations were not only guided by the inputs from the community and the constraints mentioned above, but also by the overall visions or objectives of the team members. As mentioned in Chapter 6, the team's largely shared objectives were that the model should ensure 1) Broad access to electricity services, 2) Economic viability/sustainability, expandability, 3) Well-functioning operation and maintenance, 4) Gender and context sensitive planning, implementation and operation, 5) Modest investment level, 6) Replicable/scalable system. It was implicitly assumed that these objectives were also in the interest of communities like Ikisaya. The following sections present some of the basic considerations important for the socio-technical design, the way it was defined before actual start of operation.

7.4.2. Considerations on electricity services to be provided

The selection of electricity services was related to objectives of broad access, economic sustainability and modest investment. The team found that the services should be those that a large portion of the population wanted to prioritize and could pay for, as far as it was

[66] The technical equipment was funded by contributions from different persons and organizations, saved gradually during 2009-2012, including individuals in the research team, the Research Council of Norway, other individuals, Givewatts and DFID.

possible to know this before the actual implementation. The provision of services could be adjusted later according to demand. In order to achieve economical sustainability the services should also be possible with a small battery bank because this would reduce future expenses for battery replacement.

There was not much discussion on the basic services to include, as the team agreed that these were feasible and broadly demanded by community members. Such unproblematic services included lighting, phone charging, photocopying, typing, printing, TV, video and music, and meeting facilities. The idea of using portable lanterns in order to get electric light had been well received in the community. The lanterns can be carried around and used inside and outside, in the same way as the kerosene lamps that people are used to, at the same time as they give much better light. A renting model was expected to suit broader groups than a model based on purchasing lighting systems. A gender expert in the team argued that particularly disadvantaged groups (e.g. single mothers) could have a special tariff, and this idea was later communicated back to the village for further discussion, but was not implemented.

The team did not include electricity services that would require a larger system, such as the use of fridges or blenders, because it would lead to a larger battery bank, which could become an economic burden on the whole power supply and thereby on the community. The rooms full of batteries observed in India had clearly illustrated the challenge of raising enough revenue in a remote community to be able to replace such equipment every few years.[67] It was seen as unlikely that the revenue generated by people's use of additional services suggested in the meetings would increase to the same extent as the increased maintenance costs of a larger system. Many services that would require larger power supply capacity (like use of fridges and blenders) would probably also be in less demand than the basic services like lighting and phone charging, and the profitability of the potential production was very uncertain. A low investment cost was also seen as important, not least for the replicability of the model by different kinds of actors.

Another consideration was that the electricity services should not have absolute limits for its geographical outreach. A mini-grid model could only have reached to a certain distance from the power plant and most of the population would have been excluded, while the services at an energy centre could have flexible limits. Since people often walked to the village market it seemed like the energy services could have good geographical outreach. Savings on time and costs for transport to other villages to charge phones or get a photocopy of ID cards or other documents was also one of the reasons to include these services. Many features of the model were expected to make the services accessible and affordable for women as well as for men and fit with people’s livelihoods, practices and energy needs. The IT services would be provided by the staff at the center. Email and internet was desired, but the phone network in the area was too poor for this.[68]

In order to meet the needs of those who would like to own their own lighting equipment, the team found that there could be sale of some good quality, small lighting

[67] The frequency of the battery replacement depends on the battery technology, use pattern, etc.
[68] The team made an attempt to get a mobile operator to build a new tower for phone network in the area, but did not succeed.

products which people could pay for gradually. People could also get advice, installation assistance and repair of such systems at the center.

These discussions and considerations led to a relatively "minimalistic" type of electricity supply, although much more comprehensive than what would have been possible within a purely commercial approach. As expressed by one of the engineers, we attempted to "avoid over-sizing of equipment, over-investment in buildings, electric lines, transformers and other equipment compared to the needs, benefits and revenue they might generate". The team also had to accept that modest ambitions were required, and that an energy project is not a universal solution to every problem in a poor community.

7.4.3. Technical design

The main considerations involved in the technical design related to how to achieve practical and well functioning operations and maintenance, energy efficiency and modest investment costs. Good work environment for the staff was also considered. The system should be easy and practical to operate. Important aspects were also to have good quality technical equipment, a technically robust system, spare parts and equipment for expansion available. The latter was not straightforward to achieve, since some of the equipment had been imported from India. The location of the energy center centrally in the village had already been decided by the community leaders, near important places in the community (water point, school, and market area), and the name would be Ikisaya Energy Centre.

The services were going to be delivered in four rooms of a building of nearly 70 square feet.[69] Figure 14 below indicates the rooms and the main features of the technical system design including the daily capacity, for example the number of phones that can be charged a day, and the technical equipment installed for producing the amount of electricity required, e.g. sizes of solar panels, batteries, and electronic devices. The TV and "home theater system" could have enough power for some hours per day. Operation of photocopy and printing business could be done up to 4 hours per day spread over each day, and computer use up to 8 hours per day. The plan was to purchase 120 portable lanterns for rental to the households in the beginning, and increase to 240 lanterns when the demand increased.

The TV room or multipurpose room could be rented out for meetings and various training programs in the community. Technical installations like the main batteries, inverters and charge controllers would be put in the office and store. Stationary, items for sale, books, record books, toner, and the safe, would also be kept there. The figure also shows the main technical equipment that was going to be purchased. (The technical concepts are explained in Chapter 1.)

[69] A Norwegian architect had provided a drawing for free.

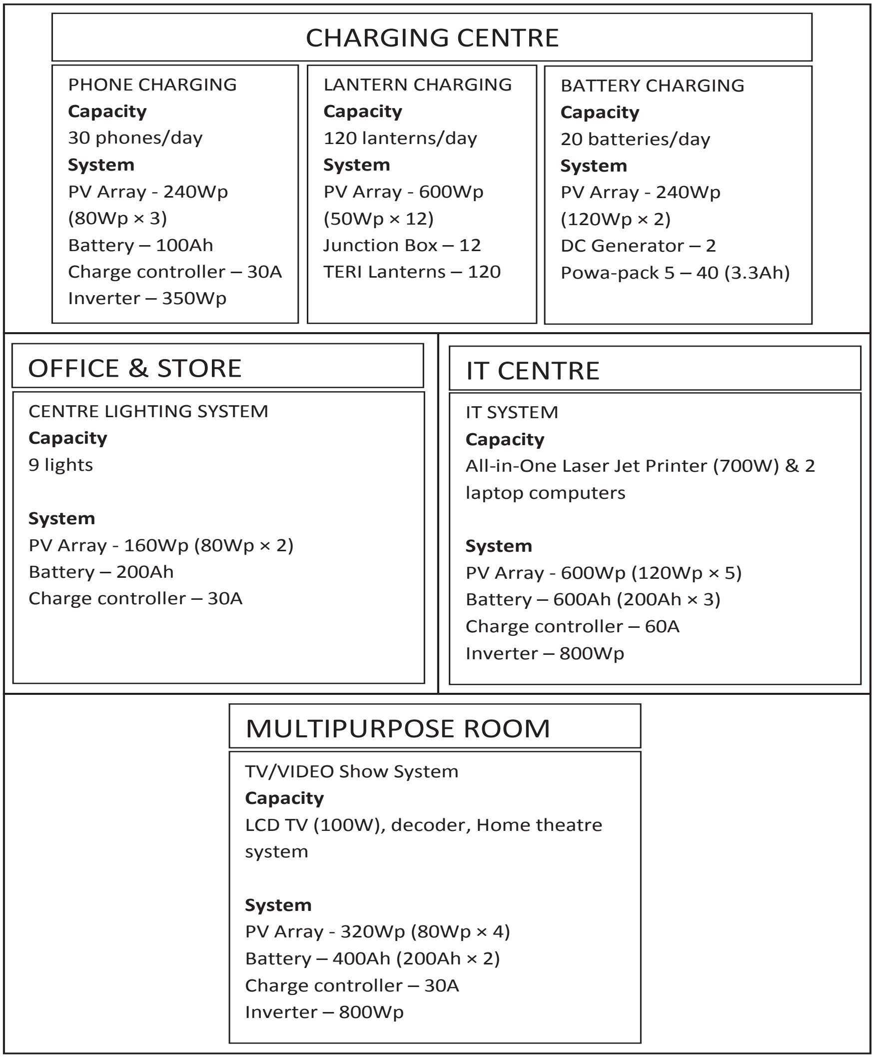

Figure 14. Layout of the rooms of the Energy Centre and the technical design. Figure made for planning purposes in 2011 by Charles Muchunku.

Based on the estimates for the demand and ability to pay for the services, the total size of the power plant became 2.16 kW only, very small compared with the Sunderban power plants. The total cost for the technical equipment and the building for the centre as described above was 4,678,000 Ksh (42,200 €).

An idea by the Kenyan engineer in the team for easy operation was to split the technical design into six separate solar systems with their own batteries, charging regulators and other electronic devices as listed in the figure above. This would prevent total shut down if there would be a fault somewhere, since the other parts would still be operating. It could also make it easier to stay within the limits for how much power could be used. Even during rainy seasons in this geographic area, there is still a few hours of sunshine on most days and sufficient light to charge the batteries. One day with minimal charging could be tolerated, because the main batteries could hold enough power for two days.

Technical equipment available from India had opened up opportunities for the lantern renting. The Indian partner organization had been working with Indian lantern manufacturers to improve the design and quality of this lantern. It appeared to be simple and robust. The lantern gave 360 degrees lighting, and had three brightness modes. It could provide 5-6 hours of light in full brightness mode and 7-8 hours in dimmer mode and took 5-6 hours to charge on a clear sky day. It gave good light (250 lumen) which was well suited for reading. A problem with some of the other solar lanterns available as was seen later, was that they had weaker light and fewer hours of use between each charging. The lantern battery was a 6V lead acid battery which could have a life-span of 1-2 years. The Indian lanterns were energy efficient – 10 lanterns could be charged every day by a 50 W solar panel.

Since the lifetime of the lead-acid batteries decreases significantly with deep discharging (also called deep cycling) it is affected by the way in which it is used. The plan was therefore to change battery technology to lithium-ion (li-ion) batteries the first time of batteries replacement. These were going to be available later, and would have a longer life and be less sensitive to deep discharging. However the technical experts later learned that li-ion batteries are also to some extent sensitive to deep discharging, although less that lead-acid batteries. They provide around the same hours of light. However, the lifetime of these batteries is likely to be longer than that of the lead-acid batteries, which would have implications for the chance to sustain the power supply economically.

7.4.4. Economic design

In discussions about the prices for the services, team members referred to the prices for similar services in other parts of Kenya, affordability of the lighting service for the households in Ikisaya compared with current expenditure on energy (kerosene, torch batteries, etc.), and the considerations for the economic performance of the center. An important goal was to keep the costs of various services sufficiently low for ordinary households, at the same time as using business thinking in operation and maintenance. The team had realized that affordability for all was a challenge, because of the extreme poverty of many community members.

Prices were suggested by the team and later discussed in meetings in Ikisaya during the final consultations before installation. Table 8 shows the prices used at the start-up time. The rate for phone charging was set at the standard rate in Kenya, 20 Ksh per charge. Lantern renting was put at the same level, for two days of renting. IT services were also set at similar levels as in other places in Kenya. Daily use of lanterns at 20 Ksh per two days would cost 300 Ksh per month, 50 Ksh below average exependiture found in the survey, and give better light than kerosene. The prices were not calculated according to the actual costs for providing these services, because it was not realistic to achieve recovery for the investment costs given the high poverty level in the area and considering the social goals of the work.

However, the idea of business thinking for the operation and maintenance became important, as will be seen further below.

Table 8. Services and price list for Ikisaya Energy Centre at start-up.

Electricity services	**Cost**
Phone charging	20 Ksh (0,18 €)
Lantern renting for two days	20 Ksh (0,18 €)
Photocopying per page	10 Ksh (0,09 €)
Typing and printing per page	30 Ksh (0,26 €)
Printing alone, per page	15 Ksh (0,13 €)
Laptop charging	350 Ksh (3,2 €)
News on TV	10 Ksh (0,09 €)
Other TV programs	20 Ksh (0,18 €)
Room hire, full day, with electricity	1000 Ksh (8,89 €)
Room hire, full day, without electricity	400 Ksh (3,55 €)
Room hire, evening, with electricity	500 Ksh (4,44 €)

The team knew that some people might not be able to afford to use the key service, light, unless it would be given for free, but free service was not regarded as an option. Later, it was realized that the price for lantern renting was too high for many people in Ikisaya and surrounding villages. The team's focus on interpreting the quantitative data obtained in the survey in Ikisaya was not sufficient. For different reasons, too much emphasis was put on the simple result of average expenditure instead of also checking how many people who had an expenditure below the average amount.

A way of taking the affordability challenge into account was to ensure flexibility regarding when and how often to use the services. People could then avoid a permanent, monthly subscription, and rather go in and out of the system as they wanted. The use of the services could be adapted to people's variable incomes and to the economic stress that peaked during drought periods. It was also seen as important to have low entry costs.

The team had observed in India and through practical work and literature that payment collection from the customers can be a problem in electricity supply systems, as shown by Winther (2014). The idea for the Ikisaya model was to avoid the problem by facilitating payment for each service before receiving it. No metering and monthly tariff collection would need to be worried about. However, some challenges nevertheless appeared in relation to payment as discussed in Chapter 8.

In order to achieve economic sustainability it was seen as necessary to take a commercial approach to operation and maintenance. The expenses, prices and estimated demand had to be balanced, and the saving of a certain amount every month for later battery replacement and other maintenance was crucial. The estimates of the future demand for the electricity services were important because they would determine many of the characteristics of the system. The details of the technical design, the budget for operation and maintenance, including members of staff and salary level would be based on the estimates. People's future practices had to be estimated, based on possible price levels, etc. Even with all the inputs and research results from the community, the estimates made by the team during the planning process later appeared to have been too optimistic, including a monthly revenue of more than 88,000 Ksh and this appeared to have large consequences for the challenges met after implementation.

One of the uncertainties in designing the power supply was the question of what kind of salary level could be possible to provide. The sub-chief in Ikisaya had earlier suggested 3000 Ksh per month per staff member in the beginning, and a gradual increase along with increased income of the energy centre. This was similar to the salary of the water attendant and teachers without training. Trained teachers had a salary of around 10,000 Ksh per month. According to the optimistic estimates, it seemed like the revenue of the centre could be able to cover expenses of 60,000 Ksh per month. It was therefore seen as possible to have a salary budget of 30-40,000 KSh for the staff. It was regarded as important to provide salaries at a level that could motivate the staff to do a good job and to be interested to stay in the village. In the final monthly budget the expenses were planned to be the following:

Table 9. Budget for monthly expenses at the Ikisaya Energy Centre.

Type of expenses	Cost
Salaries per month	30,000 Ksh (271 €)
Stationery, transport and petty cash	9000 Ksh (81€)
Saving for the battery fund	21,300 Ksh (192 €)

The team expected that the centre could reach this level of monthly results after three months of operation. As will be seen in the next chapter, it took time and effort to achieve a good economic performance.

7.4.5. Important rules for the lantern renting

Some rules would have to be followed for the renting of lanterns to ensure correct use of the technical equipment and secure the revenue for the energy system. The portable, electric lanterns could be rented out to people for two days at the time. People could pick up the lanterns at 5 pm, fully charged, and bring them home for use on that evening and the following evening. They would have to bring it back before 11 in the second morning so that it could get fully charged during the day. A fine for delayed delivery was expected to prevent people from breaking these rules for using the services, but this did not become easy in practice as shown in the next chapter. The phones would be charged during the day and should be delivered at 4 pm at the latest, to be ready to be collected before evening closing of the charging services at 6 pm.

An uncertainty here was whether the procedures for lantern renting could be aligned with the timing of the other errands of future users. Other concerns and uncertainties were the walking distances for the potential users and whether it could be manageable for people to come every second day. Ideally they could have been allowed to stay with the lanterns for additional days. On this point it was the technology itself that set the limitations, since the lantern batteries could get harmed with less frequent charging. It was agreed that the lanterns should be carried back and forth to the homes by adults, to avoid children playing with them or losing them somewhere.

7.4.6. Which organizational and operational designs at the village level could work?

Based on Kenyan team members' experience from other places in Kenya, there was uncertainty of how a CBO model (as explained above) could work, but the village leaders had suggested it and the team did not see any feasible alternative for Ikisaya.[70] It seemed to work well for the water supply in the village. However, the solar power project was more complicated, because it would be more work intensive, provide many different services, have more technical equipment, involve larger revenue and expenses and require a strict saving regime to be able to raise the amounts needed for battery replacement. It would be a registered business and require annual audits. The team also saw important opportunities of the CBO solution. Local organization, ownership and democratic management of the energy centre could be a valuable opportunity for community members to develop new skills and capabilities. The CBO would manage and operate the power provision while the project team would remain the owner of the equipment. The latter was based on experience from a community project in Kenya where the local actors sold off the equipment when they could no longer sustain its operation. The team rather wished to be able to move the equipment to another place in such a situation, after all possible measures had been tried in order to keep it operating.

There was some concern in the team that sitting allowances for the board could become an economic burden on the power system, and the team had therefore suggested that allowances should be avoided. When presenting the final ideas in Ikisaya the team got an impression that some board members were more interested in getting allowances for meetings than in doing an effort for the project based on genuine interest. Later, we came to understand that this could partly be due to a misunderstanding and lack of thorough communication on this issue, and that allowances were given in the water committee. However, it increased the uncertainty in the team of the workability of a CBO solution.

The staff was expected to play a key role for how the Energy Centre would function. This view was shared by the team members, and it had been seen in the Sunderban villages. One of the most experienced solar power supply experts in India had also expressed that the success of village power supply depends on the skilled individuals that operate them on a daily basis. Therefore, when board members showed concern for the workload and suggested sitting allowances, the team therefore ensured them that the paid staff could do the bulk of the work. The CBO and its board was going to have the overall, formal responsibility for the power supply, as voluntary, unpaid work. Team members argued that the board should have

[70] Such a centre can also be run by an NGO or an entrepreneur.

a low, reasonable workload, and anticipated that suitable roles for the staff, the CBO, and board could be developed through information, support and gradual learning. There was some disagreement in the team on how much training the board would need and which role they would play. A good information flow between the board and the staff was aimed at. The following staffing was suggested:

- A charging attendant responsible for the lantern charging and renting, battery charging, phone charging and retail shop operations.
- An IT-clerk responsible for operations related to printing, photocopying, computer services, laptop charging as well as managing the TV/Video room.
- A part-time book-keeper responsible for preparing weekly and monthly financial statements, preparing the pay roll and general preparation and filing of records, receipts, bank statements, and reports for the annual external audit.
- An evening attendant responsible for fee collection from the TV/Video shows screened at night, night-time security and general cleaning.

An additional position of energy centre manager was also created, although the initial plan was to have one of the abovementioned staff members to undertake this role. The energy centre manager's responsibilities comprised of reporting to the executive committee, proposing operational changes, consolidating energy centre records daily, preparing weekly reports and documentation for the accountant, collecting the daily revenue, depositing of the cash in the Energy Centre bank account, budget preparation, etc.

Could all the staff members be local residents, or was it necessary to hire somebody with a technical background from other places? There was agreement that one of the staff members should have some technical knowledge, but there was disagreement on the possibility to train somebody on this from "scratch". Local job creation was regarded as very important by community members, and some team members argued that this should be prioritized over finding a technically skilled person. Gender was also an important issue, and some team members suggested that technical education should not be put as a condition for all staff members so that women and other local people could get a chance even without a technical background. An 8-9 days intitial training and some follow-up training to the staff was planned, including support and advice after implementation, especially for the first year of operation. In meetings with village leaders and community members, the team insisted that there should be 50% women in the staff and board. Team members also used women as assistants during research to be able to have good conversations with women in the community and to give training and encouragement to them.

7.4.7. Considerations on how to achieve replicable design for widespread implementation

Replicability was seen as an important aspect to consider, despite the strong focus on the pilot project. One argument was that the best way of making the model up-scalable would be to make it economically profitable so that the private sector could "roll out the model". Partial cost recovery was also regarded as useful. There was a recognition that cost recovery could be difficult, due to the low ability to pay in poor, remote communities and because some variety of services should be provided – something more than private sector actors could already do. Achievement of an economically sustainable model was seen as a difficult task in itself, as had been seen in India.

Another argument was that the private sector tended to prefer geographical areas where the opportunities for profit are larger, and to serve those portions of the population with the highest ability to pay. Moreover, it was argued that it is government's responsibility to invest in provision of infrastructure, and that a low-cost, cost-effective and economically sustainable model could be replicable for the government. Replication by NGOs tended to be ranked lower by team members, more as a solution that could lead to some sporadic replication, but with less potential than the private and the public sector.

The team saw it as important to use equipment suppliers in Kenya in order to demonstrate that the equipment for a village scale solar power supply was available in Kenya. Use of suppliers in Kenya would also facilitate contact between the local people and the suppliers in case of warranty issues and needs for repair. The team nevertheless used some equipment from India in order to create a good system for charging portable lights.[71] A task for the team was to find or make all the necessary equipment and spare parts available in Kenya.

Another consideration on how to make the model replicable, especially in Kenya, was to take the national framework conditions for implementation of solar PV systems in Kenya into account. The model should not include elements that would not be compatible with Kenyan policy on off-grid electrification, to avoid barriers for replication by the government or other actors. Lack of funding support for capital costs in community energy systems was mentioned as a barrier to replication. An issue discussed several times both before and after implementation was how to make the model replicable in terms of fulfilling needs for advice and follow-up of village level energy systems in the long term perspective. A long-term task for the government could be to build up novel institutions for such support. However, since such structures were not yet in place, the team attempted to create a model that could be replicable without such institutional frameworks, possible for local people to operate with minimal support from the outside after a period of establishing the activity.

7.4.8. The community members' feedback on the teams suggestions

The team went back to Ikisaya and presented suggestions based on the team's considerations described above, two times in two months. In the last community meeting the Energy Centre "design" was presented in Kikamba language by a young woman from the village who later became the manager of the solar power plant. The participants were curious to know how the Energy Centre would work, and asked many questions for clarification. They were amazed about projected revenue, and the team said that this is an estimate which might not come true.

[71] Lessons were learned about the challenges of importation, both practical procedures and costs, and that it is easier for established importers.

Some asked who would get the jobs, and whether individuals would benefit from the business.

One comment concerned the suggested price for photocopying which was higher than in Endau and Kitui. A team member argued that the saved travel expenses will compensate for this. The price was reduced after the start-up due to pressure from community members towards the staff. Another comment from the audience was that the suggested salary for the evening attendant was too low because the job would be double, both to take care of TV shows in the evening and to guard the centre during the night. The team took this into account when revising the budget estimates. The team also met with the sub-chief, the village leaders and the interim board, which had already been elected, as explained below. The procedures for staff selection were discussed. During individual conversations with leading persons, some suggested to take staff from other places in order to get sufficiently skilled staff while others disliked this idea.

7.5. The implementation process in Ikisaya village

Important parts of the implementation process were the formation of the CBO, the design and construction of the energy house, the CBO's hiring of staff, and finally, training and installation. These took place in Ikisaya in parallel with the process described above, in cooperation between the team and community representatives in Ikisaya.

7.5.1. Formation of CBO in Ikisaya with considerations about political factors

The village leaders asked the team to give advice on by-laws for the CBO[72], and the team provided an example and some advice. As part of the strategy to adapt the project to the local context, team members had asked the sub-chief whether clans and family relations could create problems, and how broad representation could be achieved. He said he viewed the clan system as old, and something that he was not interested to use as a criteria for membership in the board. The important issue was to ensure representation from different geographical areas (six different wards or sub-villages in Ikisaya[73]). This would also balance clans because of the way they were distributed in the area. A public meeting of 30 people elected an interim board. The sub-chief and his community leaders' committee were present. The participants also suggested many changes to the draft by-laws, which went back and forth between the community and the team three times.

The interim board and executive committee represented a mix of people (families, geographical areas, and clans), but the the chairman of the interim board appeared to be a half-brother of the team member from the village. He had already acted as a spokesperson for the community leaders in relation to the project. Kenyan team members expressed

[72] Such by-laws state the rules for the CBO, including how to elect the board, decision-making procedures, banking routines, all responsibilities of the board, etc.
[73] Kyanzou, Mwalikanzi, Ndovoini, Ngiluni, Ngovovoni and Kalwa.

scepticism to this family connection.

The community leaders formulated goals for the CBO that went beyond the goals for the solar project, expressing visions for the long term contributions of the energy project. They included:

- Managing the establishment, operation and expansion of energy supply in Ikisaya according to demand
- Creating jobs and business opportunities
- Improving water supply by sinking boreholes and providing pipelines
- Utilization of natural resources in the community, for example forest products for the benefit of the community
- Other community development activities such as improving access to health and education facilities

7.5.2. House construction, tender process, and delays

The equipment for the Energy Centre was purchased through a public tender because part of the funding came from public sources and had to be used according to rules for public procurement. One of the engineers in the team worked out a comprehensive tender document, and the tender was announced in Kenya. Ten of the 15-20 major suppliers of solar equipment in Kenya gave bids, and a supplier was chosen based on quality and price. The lantern charging system (junction boxes and lanterns) was imported directly from India. Some delays came up during the tendering and import of equipment from India and it became necessary to postpone the whole installation for two months. This created a few complications, including uncertainty for the local actors, which the team attempted to compensate for by paying salary to the staff during their waiting time.

The team did not involve the community members in this procurement and importation, for several reasons, most importantly because future purchase of equipment would be much less complicated. It would not be relevant to carry out a tender process, only to contact Kenyan suppliers, check prices and order equipment, first and foremost replacement batteries, but also other spare parts or additional equipment. The team could assit the staff and board so that they could learn it the first time they would need new batteries and additional equipment.

The project team introduced an idea of using a container or pre-fabricated solution for the building for the power supply, in order to reduce the costs and make replication easier because of simpler construction. This idea was strongly opposed by the community leaders because they feared the heat inside, and the team therefore built a house as first planned, using a local contractor.

7.5.3. Giving away control – CBO hiring staff in the village

The CBO board hired staff for the energy center, while the team assisted on the job descriptions and gave advice for the job interviews. The team wanted to gradually give away control, so that the local actors could get a chance to learn as much as possible. However, it was not easy for the board to know which kinds of skills, qualifications and qualities the staff members should have. Seen in hindsight after the challenges described in the next chapter, the team could have kept slightly more control of the hiring process and thereby saved all involved people from concerns and efforts.

The hiring process was carried out in a thorough way with a neutral committee consisting of four of the executives – the chairman, treasurer, vice chairlady and secretary (from four different families and clans) and two officials from two neighboring villages. Commitment to the project was one of the most important criteria that the hiring committee applied according to one of the executives, and two of the selected staff had worked as research assistants for the team.

7.5.4. Training and installation

During the time of installation, training and start-up, three team members, an assistant, and two technicians from the equipment supplier stayed in Ikisaya for 9-11 days. All these were Kenyans except for the team leader. The technicians from the Kenyan equipment supplier carried out the technical installations. The supplier as well as the technicians had experience from solar installations in Kenya and in neighboring countries. A Kenyan team member (solar energy expert) instructed the technicans and discussed with them on the details of the technical installations and made some technical changes underway. A challenge was that the supplier had not included a stand or rack for the solar PV panels. The team member designed a rack on his laptop, and a technican took the drawing to Zombe 50 km away, coming back two days later when a local welder had done the job on making a large metal rack. There was a constant need to come up with new ideas and solutions, mostly on the social aspects, but also on the technical aspects, and in this case combining existing technical services locally (welding) with the engineers expertise.

An episode that illustrated the consequence of connecting a heavy load to this solar system happened during the installation of a parabolic antenna for the DS-TV. A technician had come from Kitui town to do this specific installation. This was on the first or second day of having electricity at the Energy Centre. The visitor observed it when he arrived after dark, since the centre glowed as a star in a vast darkness. He plugged in his drill in a socket inside the Centre and switched it on, and suddenly the power went off. The Kenyan experts laughed, and said that this was a very good learning experience for staff members at the Centre of what happens if they plug in electric appliances that are larger than what the system is designed for.

During these days there was a strong attention to the technical components, because this was the time when all the equipment was put in its right place, inside and outside the house. The two technicians sweated on the roof, connecting all the cables, pulling at least 20 cables down to the installations inside the house, trying to cope with the hot weather. Even the Ikisaya people were affected by the extreme heat, but there was nevertheless excitement in the air.

In addition to the focus on technical design, the other main focus was on the training of the staff, which was going on in parallel. This was also led by the same Kenyan team member. The training included several different aspects of the operation, from technical working of the system to balancing of revenue and expenses, as well as operational routines, service delivery to customers and a detailed system for book keeping. The team member invited the staff to suggest improvements in the system design during the training sessions, sometimes even overruling decisions made through the previous, long-term research process and collective considerations. Meetings with the board were held on the first and last day of the installation period.

After the last, hectic clearing, cleaning and putting the last equipment, record books, cash boxes and receipt books in place, the centre was ready to start operating. The prominent idea about the information for community members at start-up was that the local staff would provide the necessary information through their own marketing activities and by explaining the services when people came to the centre to see what it could offer. Therefore, no information meeting with team members present was organized for the community at this point in time. However, the community members would probably have appreciated a meeting, since they were used to getting information from the team during the planning process.

7.5.5. March 20th 2012: The Energy Centre has started operating

The opening day was a special day for the staff and project team members. Many people came to have a look and ask questions, and the staff did well. The sub-chief was one of the first customers, finally being able to get copies of his papers within a five minute walk from his office. There was no grand opening, since the team found it important to let the staff start getting used to their tasks without a crowd of people around them.

Team members stayed around at the centre for the first 1 ½ days after opening. Initially they had planned to stay for a week, but this was not possible for different reasons. An idea was also to let the staff learn through the practical experience of operating the Centre on their own. Perhaps some of the coming challenges could have been discovered at an early stage if they had continued to stay around at the centre for some days. However, this is not possible to know, and the learning process that followed appears to have been useful. At least it came to illustrate some of the complexities of introducing new technologies in the context of existing practices and societal contexts, as will be explained in the next chapter. The challenges forced the involved actors to understand that the ideas that looked so good on paper had to be changed to a larger extent than what they had anticipated.

7.6. Concluding remarks

The process of "socio-technical innovation" at a small scale described in this and the previous chapter finally led to an actual, local socio-technical system in operation in Ikisaya village in Kenya. A crooked road was walked during the socio-technical design process described above. The process was both planned and flexible, based on requirements that emerged underway. There was an iterative learning process with the Ikisaya community going back and forth several times. The pathway taken by the team towards the socio-technical design for Ikisaya went out in the open, was searching and explorative, with many unknowns. A range of contextual factors, limits and uncertainties influenced the emerging solutions and the extent to which the users' ideas and suggestions for the electricity services had been possible to take into account. The route ended up relatively near something that had been observed at an earlier stage, but not taken so much into account until later, the charging station model (described in Chapter 1). This model had been briefly observed in India. This does not mean that there was little learning from the Sunderban mini-grids or other projects in India, Kenya or elsewhere. Many of the ideas that came up were based on difficulties observed in other projects.

The ideas for the socio-technical design for Ikisaya gradually changed as a consequence of an increasing understanding of the societal context at the local level. The wider framework conditions in Kenya were also kept in mind. It was also influenced by the exchange of ideas, knowledge and experience in the international team, the methods used, including the trans-disciplinary approach and new types of equipment available. Co-incidence, luck, accidental factors and personal relations also played a role. The learning from India was thereby interacting with a range of other factors, knowledge, experience and visions.

The Ikisaya model was developed almost independently, even though it could usefully draw on technical equipment and experience from India. The Indian team member's familiarity with charging stations gradually became important, and the team was dependent on getting the right technical equipment from India. The Ikisaya model nevertheless differed significantly from both models seen in India, both the one thoroughly studied and the one briefly observed and later further explained by the Indian team member. Thus some "new combinations" had been created.

There were both similarities and differences between the Sunderban example and the Ikisaya model as planned on paper. The main differences are shown in the following table (Table 10). The Sunderban model is described the way it was observed during the fieldwork. The various mini-grid systems in the Sunderban were not uniform, but most of the features mentioned below were common for all those studied. The Ikisaya model is described the way it looked at the time of actual start of operation.

Table 10. The main differences between the Sunderban model and the Ikisaya model.

The Sunderban solar mini-grids	The socio-technical design for Ikisaya
Gridlines to the houses	No gridlines
Power supplied for fixed hours in the evening for lighting, phone charging, TV and fans. Photocopying and typing services provided by electricity customers	Power used when needed, but for limited time, for lighting, phone charging, photocopying, typing, and TV services. Retail shop at the power plant
Monthly payment for electricity, fixed amount at two levels	Payment upfront for each service, no fixed payment
Large system (relatively), 25-110 kW for 300-500 households and other customers	Small system, 2.1 kW for lighting for 240 households and various services
1-2 operators in a plant, mainly doing technical tasks, but also negotiating with local people (committees, customers, etc.) about problems	3-4 staff members, doing a variety of tasks. The customers and the staff meet face to face every time the customers use the services
Staff has little freedom to influence the business, but their commitment is important for the technical performance of the electricity provision	Staff has large freedom to influence the business, and large responsibility for the viability of the system
Only men as staff	Women and men as staff
Owned by the government	Owned by a CBO, while the implementer owns the technical equipment

There were also similarities between the two models, not least in the challenges met after implementation, as will be seen in the next chapter. Similarities in the system designs, apart from using solar PV at the village level, were the emphasis on electric light, the grant funding, the emphasis on local management and the implementers willingness to work with the local actors. However, there were differences in the details of these aspects.

The chapter shows that even before the team had come as far as trying out anything in practice, the activity of transfering knowledge and experience from India to Kenya had been a comprehensive learning process. Much emphasis had deliberately been put on this "socio-technical design" phase, both through the interaction with the village community and by the use of social science studies as part of the design process.

The chapter has also shown that early phases of socio-technical experimentation involve predictions of the future actions and practices of social actors. Project implementers and others who are involved in the design process make assumptions like "if we do this, other people will do that". Even if the potential users have participated in the planning, only the actual functioning of the system can show what the users will do, not only in the beginning of the operation, but also over time. Chapter 8 presents the analysis of how the Ikisaya model worked in practice for the community, and how the involved actors continued to change it.

Chapter 8: The Kenyan case (III): Confrontation between ideas and real life challenges

This chapter analyzes the functioning of the energy system in Ikisaya and the qualities of the electricity access for the users during the first two years after implementation (March 2012 until March 2014)[74], and how the process of developing a socio-technical design continued. The guiding question for the action research carried out in this phase was: "How can the solar power model be adjusted and improved based on practical experience and academic research after the energy system has started operating?"

The two levels of research that run through this dissertation, continue also in this chapter. At the first level, the chapter analyzes the way in which the socio-technical design appeared to work in practice, how and why it changed over time, the electricity access achieved and the system's potential for replication (corresponding with the dimensions D, E and F of the framework of analysis presented in Chapter 3.) The dimensions analyzed in the previous two chapters (the national framework conditions, the local context and the planned socio-technical design, dimensions A, B and C) are kept in mind also here, as will be discussed, because they influenced the actual functioning of the model and some early attempts to replicate it.

At the second level of research, the chapter gives insights in an important phase of transfer of innovations – the practical testing and socio-technical experimentation, inspired and informed by ideas and knowledge from another geographical context, constituting the main outcomes of the transfer process. The chapter shows a continued process of socio-technical learning by all involved actors, and demonstrates factors that influence such learning processes.

The Ikisaya project is analyzed in similar ways as the Sunderban project, but the focus on learning processes is stronger in the Ikisaya analysis because of the long-term participation. The Kenyan project is also younger than the Indian project, and it cannot yet be known how it will work in the longer run. As in the analysis of the Indian project, the purpose of this analysis is not to evaluate the degree of success, but to achieve understanding of factors that had importance for how the system functioned and the kinds of electricity access it gave. It is nevertheless necessary to discuss the qualities of its functioning and the electricity services provided in order to understand the underlying factors.

[74] Some data are also from the later parts of 2014.

8.1. The functioning of the Ikisaya model

Despite the anticipation of unexpected challenges in the Ikisaya case, there were nevertheless surprises and disappointments for the project team and the key people at the local level, especially during the first months of operation. The learning process had not stopped at the actual implementation, but continued in a vigorous, but different way. The role of the project team changed significantly when Ikisaya Energy Centre started operating, from having had a strong influence on the project, to a situation where the project to a large extent depended on the roles and responsibilities taken by actors in the village, as well as on the already implemented socio-technical configuration.

The team monitored the way in which the project worked, and cooperated closely with the local actors. Ideas for improvement were developed and tried out based on changing situations and circumstances, as part of action research. Instead of stating that they formed part of exiting, creative work, some of the key team members now expressed that it felt more like problem solving and repairing failure. Outsiders started to point out weaknesses of the project. However, the team members gradually realized that the continued need for improvement was a natural, necessary and even inspiring part of developing new socio-technical designs.

As in the Indian case study, the analysis of the practical functioning of the electricity provision is a key dimension of the research in Ikisaya, and the analysis is divided into the same five themes. The first theme is the mutual influence between the users' practices and the functioning of the electricity systems. The second theme is about the dynamic interaction between the technical and social elements of the system. The third theme is about the daily operation and organizational functioning, and the fourth is about the economic performance and its underlying reasons. The fifth theme is about the role of changing framework conditions on the system's functioning.

8.1.1. The interactions between people's practices and the power supply system

A crucial factor for the viability of an energy system is how users or potential users relate to it. If they use it less than what was anticipated, there is spare capacity, low revenue and idle staff, negatively affecting the economy and perhaps also other dimensions of the system. If people use it more than what was anticipated, there might be problems because of limited power generation capacity, and over-use of power might harm the batteries as seen in the Sunderban projects. Also, it might be challenging to allocate a limited amount of electricity between the different users, or to expand the system when need arises. The users' choices influence the system and the system's functioning influences the users' choices.

8.1.1.1. Surprises about low use

During the first year after the operations started, it became clear that the team's attempts to predict the future use of the services at Ikisaya Energy Centre had been too optimistic, despite the thorough planning and research process. The revenue and expenditure projected and planned for was therefore too high, and the plans for monthly saving for maintenance became more difficult than anticipated. This had consequences for most of the elements of the system, especially the chance to achieve economic sustainability.

The use of the services started at a low level, especially for lantern renting, although better light had been regarded as the most important service by the community members. During the first month in operation, only eight of the 120 available lanterns were used in Ikisaya. One reason found was that people were not comfortable with the rule of two days renting of lanterns. Early customers had seen that when they returned the lanterns they still had power. People in this place were used to economizing with light. Other factors that seemed to play a role were affordability, walking distance and routines that people were not yet used to.

The team also learned that at this time two local opinion leaders, one of them member of the board, discouraged people from using the Centre, apparently because they did not have trust in the manager and his financial accountability. One of the men owned a diesel generator that was placed in the next building where he showed TV, and his business had already got reduced due to competition from the Centre. Some people were probably reluctant to act against the will of these men due to possible dependency on them through social networks and opportunities for temporary jobs.

After meetings between the staff, board and project team members, the board held a public meeting during the second month of operation in order to provide information and get the views of community members. According to staff the 40 people who attended were positive towards the Centre and asked many questions, especially on the price of renting the lanterns, which they felt should be reduced. The board answered that this could be possible later, after all the lanterns had been taken into use. The skeptical persons now started to rent lanterns, and the number of lanterns used grew gradually over the following year.

8.1.1.2. The first, and largest change – start of agents

One of the team members suggested that since the demand for lanterns was less in Ikisaya than estimated, some of the lanterns and charging equipment could be moved to a neighboring village, such as Endau town south of Ikisaya, which is a little bit larger.[75] This was possible due to the kind of modules used for lantern charging. The staff at the Centre had already started to rent out lanterns to people in Endau town one month after implementation, taking lanterns back and forth on a motorbike. This was a logistically complicated job, because the customers were not always present, and the lantern ended up staying for extra days, which increased the risk of deep discharging of the batteries.

The staff, board and project team agreed to move some charging equipment and some of the lanterns from the Centre to two neighboring villages, Endau town and Malalani[76] and a remote, small village within Ikisaya itself, Kalwa, about 10 km from the Centre.[77] Some solar

[75] Endau town, also called Ndetani has 693 households (Republic of Kenya 2010).
[76] Malalani village has 325 households (Republic of Kenya 2010).
[77] The map in Chapter 7 shows the location of the different villages.

panels, junction boxes and lanterns were installed to existing shops or other buildings in market areas. This was the start of the so-called agent system, which made the Ikisaya model cover an increasing number of villages instead of one. Some of the board members in Ikisaya as well as a part of the team was reluctant to take equipment away from Ikisaya, but they later agreed that it was better to let the lanterns be used in other villages than letting them stay unused in Ikisaya. There would still be enough lanterns left, and more could be provided if demand grew, according to the initial plans. One year later, agents were also started in Kathua and Yiuku villages[78] around Endau town.

In some cases, the organization of the agents implied that shop owners rented out lanterns and got a commission, and in other cases a person was hired in order to do the job. The Energy Centre staff identified and trained the agents, followed up the operation, checked the records, the customer treatment, and the accuracy in book keeping. Initially the staff in Ikisaya visited most of the agents once per month, but reduced the frequency of the visits to those agents who were performing best and who could send the money by m-pesa.[79]All the agents offered lantern renting, and some also phone charging. After two years of operation the number of lanterns rented out in Ikisaya itself was around 50, while around 160 lanterns were rented out by the agents. Figure 15 illustrates the Ikisaya model with agents.

8.1.1.3. The users' delays in handing in lanterns for charging

New practices took shape among the users as technologies gradually became part of everyday life, work and routines. The portable lanterns seemed to fit well for people's needs for light as will be further explained. However, many of the lantern renting customers in Ikisaya did not follow the rules that were set. They came too late for the lantern to be fully charged that day, and they often came one to three days too late. Some of the customers, many of them women, told the staff that they found it hard to come before ten or eleven in the morning to deliver the lantern, because they were busy with their household work.

Although the number of lanterns rented out gradually increased, the Centre's revenue on lantern renting did not grow accordingly due to the practice of keeping the lantern longer than two days for the 20 shillings paid. The "over-staying" (as expressed by the Centre staff) had similar reasons as the low use of lanterns initially, including the inconvenience of going to the Centre often or at certain times of the day. The difficult economic situation of most households in Ikisaya was probably an important reason. The staff at the Centre said that poverty had worsened due to the droughts during 2009-2012.

The two days rule was difficult to change since the technical equipment itself set the limits. The staff, board members and project team agreed that more information and explanation about the rules from the staff and a stricter implementation of the rules was a possible solution. Staff members found this to be important, but it appeared to be a difficult task for them to be strict with their fellow community members, because it was perceived as offending, and not culturally suitable. In Endau town most of the customers followed the

[78] Kathua has 210 households and Yiuku has 359 households (Republic of Kenya 2010).

[79] M-Pesa is a system for payment through mobile phones. In some areas the phone network was very poor so that M-Pesa was unpractical.

rules and good economic results were achieved. Possible reasons were that the customers in Endau town were mostly businesses that could afford the renting of lanterns, and thereby save on the expenditure on kerosene. They were also located at the market area and could pick up the lanterns in short time. It was also easy for the agent to get in touch with these customers in case of any problem.

There was no comprehensive community involvement during the implementation of agents in surrounding areas, due to the simplicity of the agent model, only to ask the chief for permission. An existing building or room and a little space on the roof were the only facilities needed, and services were offered just like when opening a new shop.

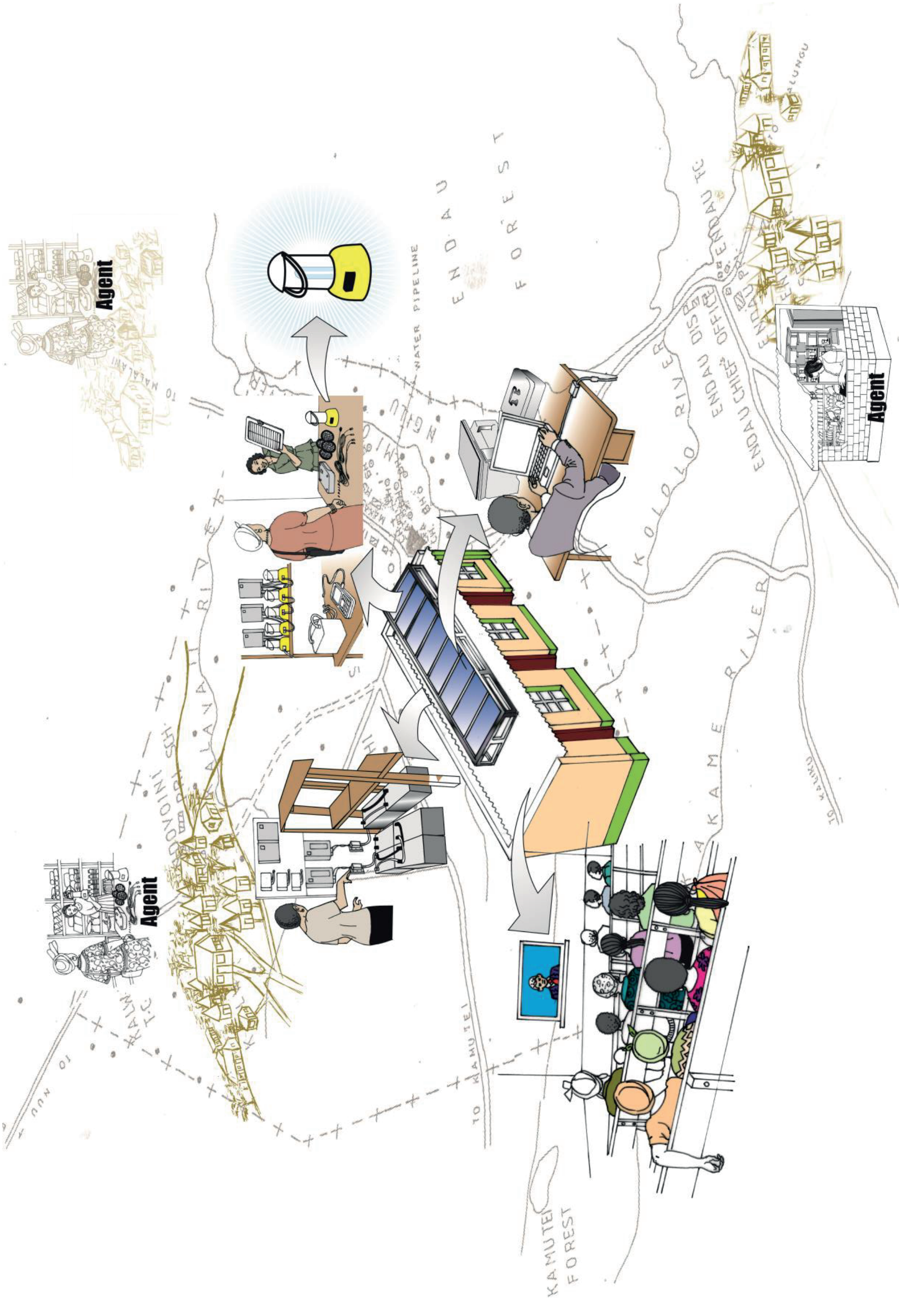

Figure 15. The Energy Centre Model after the agents in neighboring villages were added. Illustration by Mike Mabwa, Kenya.

Paradoxically, there was higher compliance to the rules and acceptance of the prices in most of the places where there was no community participation (Endau, Yiuku and Kathua). However, in Malalani and Kalwa there were nevertheless similar problems as in Ikisaya. The problems with compliance might therefore be related to a situation where households rather than shops formed a larger portion of the customers.

In Ikisaya, some improvement in compliance of the rules was achieved when one of the staff members, a young woman, started to explain the reasons for the rules systematically to every customer, and thereafter enforce fines that had been introduced earlier. Her patient and informative, but determined explanations were received positively by the users, and had effect on their routines. Her background in pedagogy most likely helped, as well as her communication skills and caring attitude. A significant change was achieved in the lantern renting, according to the financial reports. This indicated that some of those who had stretched the rules could afford to pay 20 Ksh every second day. However, others were now unable to afford continuous renting of lanterns.

8.1.1.4. People's payment for the electricity services

Another important side of the users' ways of relating to and influencing the functioning of an energy system is the way in which they fulfill their obligation to make the payment for the electricity services. Theft of electricity from electricity grids is a common problem that leads to large losses for electricity providers (Winther 2012). Such problems had gradually occurred in the Sunderban projects, but in Ikisaya it was easier to ensure that the electricity services were paid for due to the upfront payment each time a service was used. However, although it was planned that credit should not be given by the Energy Centre, it became difficult for the staff to follow this completely, especially during the worst seasons of drought and economic stress. People were used to purchase on credit in local shops, and expected it to be permitted also at the Centre. At the annual general meeting (AGM) in 2013 the staff and board urged the members to pay the debt they might have at the Centre.

8.1.2. Technical challenges and socio-technical dynamics

Although this dissertation places emphasis on the social aspects of socio-technical change, the results also show that the features of the technical devices strongly influence the opportunities for the social actors. The dynamic interaction between the features of the technical devices on the one hand, and the way they become used and embedded in societal structures and socio-cultural contexts on the other hand is important to scrutinize, as the Sunderban case clearly illustrated.

A central, technical challenge in village level solar systems is how it can be possible to avoid overload and shortened battery life. This is crucial for economic sustainability due to the costs of battery replacement. Especially when the users are connected directly to the power source through a local grid as in the Sunderban, advanced technical and organizational solutions are required. However, there are nevertheless some similar challenges in a system with electricity services provided without a local grid.

In the case of Ikisaya Energy Centre, no customer had direct connection to the power plant. Only the staff could draw power from the plant's batteries, and had control of the use of power.[80] The sensitivity of the lead-acid batteries to how they are used nevertheless affected the project, because the staff could not control the batteries inside the portable lanterns. The lifetime of these batteries was dependent on the users' practices. The lanterns even had to be switched off before the light went out to protect the batteries from degrading too fast, and this was not a realistic behavior of the users. Several customers learned about the sensitivity of the batteries when waiting for the first battery replacement for the lanterns. They had used the same lantern over time, and saw that less frequent charging led to reduced lifetime of batteries.

The lantern renting model suited with everyday practices of many people in the area because they met people's needs for moving around with the lights. But the requirement to hand them back after two days was a strong limitation. If the batteries had allowed some additional days of use, the renting of lanterns would have become more convenient. Even after switching to lithium-ion batteries in 2014, the lanterns had to be charged every second day. Otherwise, the lanterns were robust and had only a few technical problems related to dust or water inside the lanterns and small needs for repair that could be done by the Energy Centre staff. The rest of the technical equipment and the way it was configured in this case seemed to be robust and user friendly in most ways.

8.1.3. The functioning of the daily operation and organizational set-up

Well-functioning operation and maintenance (also called operational sustainability) is viewed as the minimum requirement of a viable energy system by some energy practitioners. This is a less ambitious goal than economic sustainability, which is the ability to cover recurring costs of operation and maintenance from the revenue generated from the sources provided. Even more than in the Sunderban projects, the staff (or operators) in Ikisaya came to play key roles for the functioning of the electricity provision. They also became important in training and following up agents and new staff members. Other actors that had an impact were the board and the project team in addition to the users, who had an indirect impact as discussed above. Especially the staff became active in developing the services offered, operational routines, strategic planning and economic performance, after the first months of getting used to the system.

8.1.3.1. Smooth functioning of the daily operation

Except for the challenges on being strict, patient and pedagogic towards their fellow community members who rented lanterns, most of the work went smoothly in the day to day routines, according to observations at the Centre by different team members, the board and the staff's own accounts. The system seemed to be manageable and the training and follow-up suitable, although it did not work in the same way for every staff member.

[80] It was possible for the staff to over-use the batteries, but only to some extent, because a load limiter would make the system to "trip" if a heavy load was connected.

The technical and administrative tasks of the staff were related to the lantern charging, phone charging, typing and other use of laptops and copy-machine, and use of satellite TV, DVD player and music system. Technically, phone charging and lantern charging were easy tasks, the IT services were slightly more complicated. Each of the three main staff members became able to manage the Centre alone for a whole day, although this was often hectic, shifting between the different charging services and thereby running between the different rooms at the Centre. Other tasks were the bookkeeping, planning, meetings, typing and cleaning, reconciliation of daily revenue, and other leadership and administrative work. Typing work sometimes had to be done at home in the evening. As an additional service started by the staff, haircutting came in addition (with around 80 customers per month).

The staff trained assistants when they needed it, young women, who did all kinds of tasks except from handling money and doing larger technical installations. The key staff members also acquired the knowledge of banking, long-term saving, maintenance, cooperation with the board, auditing and AGM routines. Banking the revenue was a challenge due to a long travel distance to the bank, and the treasurer of the board assisted the staff to take the cash to the bank in Kitui and bring back the bank slips. The staff, especially the female manager, tended to work for long hours. They had few and only occasional days off. The customer management in the lantern renting was often left to the manager because she was best at handling the challenges of unruly customers, as mentioned above. Therefore she often stayed late and had to walk home after dark. The team encouraged the staff to find suitable ways of organizing themselves, but there was a tendency to leave the manager alone at the Centre when it suited.

The personal motivation of staff members was varying and important for how they took responsibility. This degree of motivation was influenced by a variety of factors, including their own attitudes and interests. All staff members expressed a desire to make the Energy Centre work well in the long run. This was both to secure their own employment over time and possibly facilitate higher salaries in the future, and due to a wish to make the Centre to be useful for the community. Motivation was enhanced by follow-ups (visits and phone calls) by project implementers over time and by community members' demand, feedback and satisfaction. Another factor was regular staff meetings and collective decision making. Motivation was sometimes reduced by complaints from the community members and unwillingness to follow the rules, dissatisfactions with the salary, hot working conditions and farm work waiting to be done.

8.1.3.2. The staff's work on installation, replacement work and repair

Technical work by the staff was needed now and then, like opening up the lanterns to check inside, replacing lantern batteries and circuit boards. They also learned how to install and un-install solar panels and junction boxes. Several staff members, both women and men seemed to enjoy technical tasks and experimenting with combining technical items in new ways. "We are doing innovation!", one of the staff members said, referring to various ideas that the staff tried out. For instance, they cooperated with a team member on making a cable for phone charging with five plugs on one cable (like a hand). They also soldered cables with different plugs to be able to charge different kinds of lanterns from different junction boxes. When need for battery replacement in the Indian lanterns occurred, the staff members carried out the replacement after a visit by an Indian technician. They also replaced the circuit boards of the lanterns, due to the shift from lead-acid to li-ion batteries, and three women and one man (staff and agents) did the job.

Procedures for purchasing large technical equipment for the Centre had to be learned as the needs occurred. After nearly two years some of the larger batteries needed replacement for the first time and the project team assisted with checking the prices. The Kenyan technician who had installed the solar system was also a supplier of equipment, and did the replacement. The staff started to communicate with him directly, and this enabled consultations by the staff for service on the inverters and other check-ups. An important factor was the willingness of the technician to travel the long way from Nairobi to Ikisaya (6 hours by car) at an affordable price for the Centre, spending at least a day every time. The man expressed a positive attitude to do this job in that he "liked the project".

8.1.3.3. Challenges of leadership and management

The daily leadership of the Energy Centre was an important factor for the functioning of the Centre, because it had impacts both on the communication with the customers, the effectiveness of the staff, and the economic performance. However, during the first seven-eight months of operation, there was lack of collective discussions, planning and decision making among the staff. In October 2012 there was a situation of dissatisfaction and even tension, both within the Centre and among community members. Staff members showed frustration about lack of initiative from the board, and community members complained about little information about the financial performance and handling of revenue. A new election for members of the board was also asked for, since the first election had been for an interim board only. Moreover, it had appeared that the job was not suitable for the manager, and it was now discovered that he had "borrowed" money from the safe.

At this time of dissatisfaction, people pointed out that three individuals involved came from the same extended family and that this family had too much influence on the Centre. One was distrusted in the way he managed the Centre, one was blamed because of his lack of initiative to hold meetings and a new election, and one was blamed for giving jobs as research assistants to family members at an occasion.

The project team took part in solving the challenges met. Topics for discussion ranged from staffing situation, to the economic performance and banking routines. The team, board and staff (including the manager) agreed that it was necessary to change the manager. It was also necessary to reduce the staff by one person in order to reduce salary costs. The board promised to hold a members meeting and election. The change in management seemed to restore the trust of community members, since the complaints ended suddenly, according to the staff members.

Apart from the above mentioned situation, family (and clan) issues were generally not found to have a significant impact on the Centre's performance. This might be due to reduced emphasis on such issues in the community over time, as suggested by the sub-chief.

The way the issue was handled in the planning process (as described in Chapter 7) might also have helped, since it led to a mix of family and clan affiliations among staff and board. Disagreements in general seemed to be based on specific issues, more than on local power struggles. Close cooperation across families, clans or interest groups was observed in the board and staff, as well as in organization of funerals and weddings. During the process of hiring a new manager for instance, the first suggestion by the chairman of the board was a man from a different clan than his own.

The recruitment of a new manager was influenced by the board's preference of technical expertise as well as male leadership, despite suggestions from the remaining staff members to select the young, female staff member first hired as an IT clerk. However, when the technician got a new job elsewhere a few months later, she became the manager after all. Her good performance as an IT clerk and a manager probably led to the routinely selection of young women for later jobs, although it was initiated by the team's request for 50% women.

Another aspect that affected the Centre operations was the division of labor between staff members. From the outset, the Centre had been divided into departments to some extent, with a manager, a technician/charging attendant, an IT clerk, an evening attendant and night-guard and a part-time accountant. After the reorganization the staff started to exchange tasks and train each other. This led to more efficient operation and closer cooperation among the staff. It appeared to be important for the Ikisaya staff to be a team, have regular staff meetings and cooperate on solving problems. However, personal disagreements and frustration about colleagues actions or lack of action also occurred, and gave challenges to the new, and very committed manager.

A challenge in any project or business is that key people sometimes leave as observed in community energy projects in the UK (Seyfang and Smith 2007). After people have been trained and get work experience in a project, it becomes easier for them to get a job elsewhere. In the case of Ikisaya, the project team learned that a positive extended effect of the project was that it helped people to build up a career and thereby the economy of the extended family. It was realized that instead of trying to find ways of discouraging staff from leaving, it might be more important to be prepared for such change. Several of the staff members and agents moved on to higher education or other jobs, and the staff themselves trained six persons during the first two years. However, there was uncertainty of the possibility to find replacement for the manager. She was important for the achievements of the Centre and was strongly trusted by the community members and the board.

8.1.3.4. The actual organizational set-up compared with the planned

Figure 16 below shows the operational and organizational functioning. The upper part shows the planned set-up while the whole figure shows the actual, after the implementation of agent charging stations, which was the most tangible change. Other changes were that fewer people than anticipated rented lanterns in Ikisaya. Over time, the number of staff at the Energy Centre was also reduced. However, as the entire chapter shows, there were a range of changes taking place over time that were less tangible. The arrows between the involved actors show that the staff related to the community members in Ikisaya, the board and the executives of the Community Based Organization (CBO) and the Solar Transitions team. There was also some communication between the project team and the executives and board.

Compared with the institutional organization for the Sunderban projects, the actors involved in the Ikisaya arrangement were fewer. Another main difference was that the Ikisaya operators were more centrally placed in the lines of communication, and that women were important as staff and leaders. The Sunderban project was much larger.

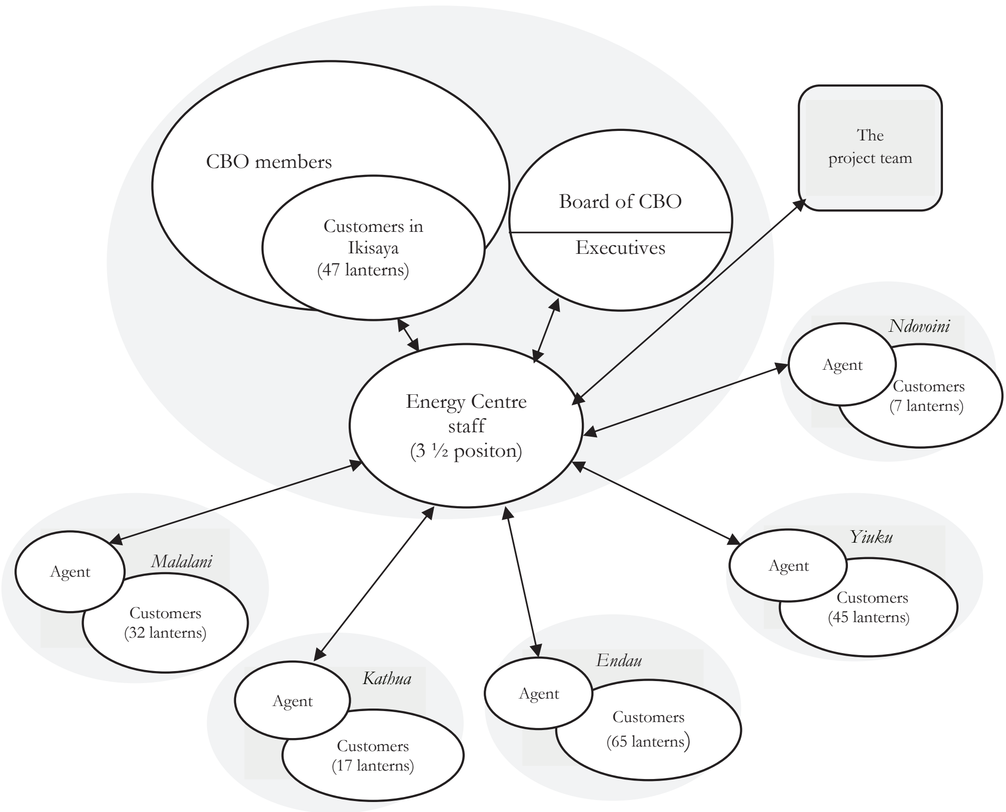

Figure 16. Outline of the practiced organization of the operation and customer management for the Ikisaya Energy Centre and agents two years after implementation.[81]

The by-laws had a requirement of having 2/3 of the CBO members present in annual general meetings (AGMs), and this appeared to be a challenge. The registration of members for the

[81] The upper part outlines the organization the way it was planned. The lower part shows the agents, which were the major change.

CBO started before anybody knew how the Energy Centre would operate. The registration fee was low, and many people registered, probably in case the membership could give benefits later. However, less than ¼ of the members later attended the members meetings and AGMs. A second try was therefore necessary in order to hold an AGM, since the by-laws allowed lower attendance at the second attempt of holding the meeting.

Routinely gathering of the executives or the full board, as stated in the by-laws for the Energy Centre, was not fulfilled during the first two years, and the board mostly operated through the executives. Some of the executives of the board were educated people with jobs elsewhere, but they stayed in Ikisaya during most weekends. These key board members were engaged in many assignments, but one of the most occupied persons nevertheless took the strongest responsibility. The board held too few meetings for the CBO members, but the close interaction between staff and customers seemed to compensate for this to some extent, because the staff was sensitive to people's points of view, and had strong influence on the energy system.

The staff consulted the board (mostly the executives) when they suggested major changes such as starting new agents or closing down an agent due to dishonesty or other problems. The executives did not follow the plan of meeting once per month and check the finances and approve budgets for next month. The staff has to ask them to meet. Individual staff members took much responsibility for financial discipline and also worked hard to ensure other staff members discipline in financial transactions. The staff acquired more knowledge on important issues than the board due to what they learned through their daily jobs, and they assisted the board before and during members meetings and the AGM.

8.1.3.5. Monitoring and follow-up by the project team

The follow-up by the project team contributed to the functioning and gradual change of the Ikisaya system, although there were problems that remained unresolved as shown in the section on financial performance below. The overall purpose of the follow-up was to contribute to a viable system, ideally independent of assistance from the outside. The literature on village level power supply does not provide much knowledge on how implementers of decentralized infrastructures can assist the local actors to become as independent as possible. An exception is a recent contribution by Ahlborg and Sjöstedt (2015), which indicates that good follow-up over time by project implementers can be important in order to achieve independence. Independence could mean that there would be no need for economic support, technical support, assistance to get spare parts and do large re-investments in batteries, or other kinds of assistance. A question is whether full independence in all ways is realistic (or desirable) to achieve in such relatively complex projects, and what it might take to achieve it. In village level infrastructures there might also be many ways of following up local actors, and such support could both lead to increased and reduced independence.

The team's activities to follow up and support the operation and organization of the Ikisaya project during the first eight months after implementation (meetings and phone calls) were more frequent than anticipated because of the challenges met, and continued for longer time than planned, but was still at a modest level. The visits during the first year, after start-up, took place in the first, second, third, fifth, seventh and twelfth month of operation. The visits lasted for 1-8 days, mostly 1-2 days, and 2-5 team members participated. The Kenyan team members were in majority. Close communication, especially over the first year of operation seemed to establish some common goals between some team members, local staff and some of the board members, in a deeper way than before. Independence and self-sustenance, both economically and in operation and maintenance became a shared goal.

During the second and third year there were two main follow-up visits and three to four visits by one team member for brief meetings and delivery of equipment. The team leader made phone calls two or three times per month to the staff in Ikisaya, later once per month. During these visits the team had thorough meetings with the staff, and most of the times also with the board. Additional conversations were held with individual members of the executives and the sub-chief. The team emphasized that the efforts for making the Centre function well was a learning process for all involved people. In the meetings and the phone calls, there was analysis of financial performance and other functioning of the Centre and common brainstorming about potential improvements on a range of issues, such as kinds of services, affordability, maintenance, saving, practical functioning, staffing, organizational aspects, and the well-being of the staff. The feedback from community members and the staff's interaction with the board were other topics. The staff rarely called the team, but they knew that they were going to receive phone calls regularly, and they often raised topics for discussion.

The Energy Centre staff members expressed to the team leader as well as observers that the team's care for them and the details of the Centre's operation was important for them (Stokke 2014). It gave them an opportunity to discuss the challenges met and possible solutions. During the first year, some members of the project team feared that the follow-up could hamper the Centre's ability to become independent, and there were differing views on what the best strategy would be. This changed during the second year, as it could be observed that the Centre performed better and that the follow-up was a likely reason, in addition to the practical experience that the staff had gained. Recent observations indicate that it might be important to continue to have some follow-up also in the long-term perspective, because unexpected challenges might come up, such as growing expenses that can affect the saving for future maintenance.

8.1.4. Economic performance and its reasons

The literature on off-grid, renewable energy systems puts emphasis on the importance of economic sustainability and ability to expand for a village energy system or community energy system, but also shows that these are ambitious and difficult goals, either it is in the UK, in Kenya or in India (Kirubi 2009, Ulsrud et al. 2011, Seyfang et al. 2013).

The struggle to reach the targets for saving for future battery replacement and other maintenance and thereby a situation of economic sustainability and independence became a central focus of attention for the Centre and the project team. The team had expected that the estimated revenue of 84,000 Ksh would be reached after three months of operation. This would cover the planned monthly expenses for salaries (30,000 Ksh), other operating expenses (8-9000 Ksh), and saving for the battery fund (21,300 Ksh), in total 60,000 Ksh per month. This would provide a surplus of more than 20,000 per month for expansion and general improvements in the village. The team saw it as realistic to start saving this amount from an early stage of the project. The Centre almost covered all its running expenses from the start-up day, only borrowing 10,000 Ksh for the first salary payment after start-up in March 2012. However, although some saving for the battery fund gradually was achieved, it took 10 months of hard work before the level of surplus started to stabilize around half of the monthly target for saving.[82]

8.1.4.1. The revenue trends and factors that influenced them

Figure 17 below shows the revenue trends for the period of October 2012 to March 2014, for the different services offered, increasing from around 40,000 up to 80,000 shillings, but fluctuating. The statistics for the first eight months are not consistent and therefore not included.

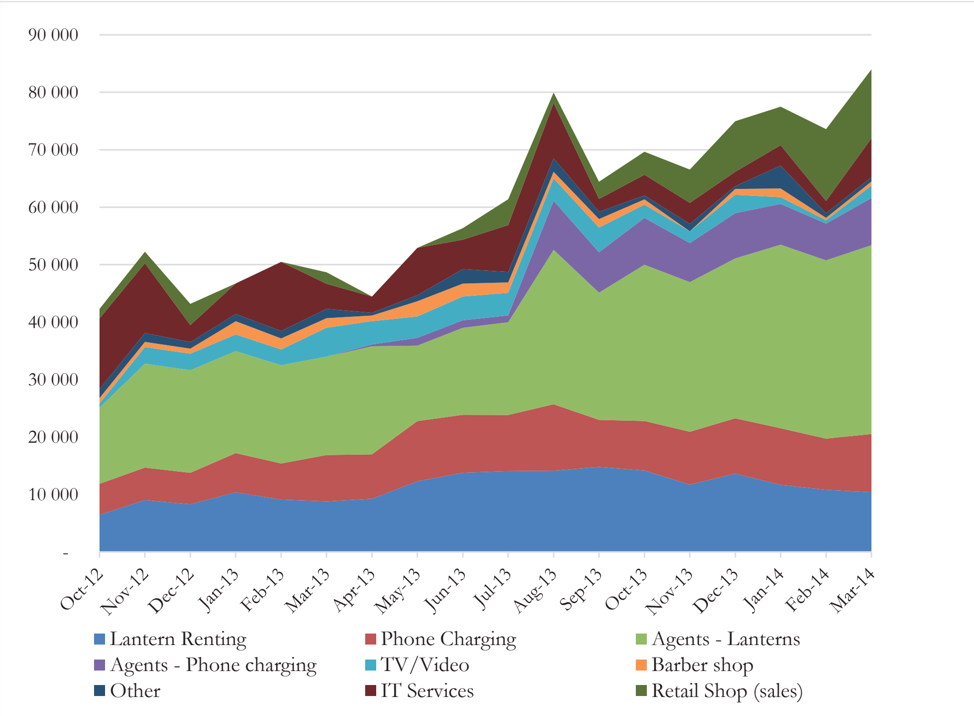

Figure 17. Revenue trends per electricity service from October 2012 to March 2014 (month 7 to 25). Based on the financial records of Ikisaya Energy Centre. Figure made by Charles Muchunku.

[82] In addition, the staff received salaries from the project team for three months before start-up as a compensation from the project for delays in the implementation phase, as explained in Chapter 7.

The renting of lanterns and charging of phones were the most important services for the economic performance of the Energy Centre, including the revenue from the agents. This is shown by the four revenue streams illustrated from the bottom up in the figure above. After two years these contributed to 70% of the total revenue generated for the Centre, and the revenue from the agents made up about half of this amount.[83]

The problems of making the customers follow the rules for the lantern renting in Ikisaya influenced the revenue significantly, especially for the first eight months of operation, and thereafter the situation improved to some extent. Moreover, since flexibility was permitted in the lantern renting so that the customers were not requested to rent continuously, the revenue was also influenced by this.

It was not straightforward for the staff in Ikisaya to know the actual revenue of the Centre's agents in other villages, although it was hoped and assumed that the amounts recorded and sent to the Centre by the agents were the ones they had actually collected. The staff at the energy Centre tried different strategies to give incentives and ensure correct recording and payment, and the degree of accomplishment varied between the agents. If they did not perform in acceptable ways, the equipment they used (which was controlled by the Centre) could be moved to a new agent. The staff did so in one case. As a result of some agents' (business owners'), lack of compliance, the staff gradually started to employ people and rent a room for the charging service. After two and a half years this system was adopted for three of the six agents. The performance of these agents was also varying, though depending both on the person and the demand in the place. Moreover, the room rent reduced the surplus. In Endau town the performance was very high, with almost all lanterns rented out continuously (80-90% efficiency[84]). In contrast, after eight months the lantern renting in Ikisaya was at 30-40% efficiency only, while it later increased to about 60-70%.

The use of the IT services fluctuated during the year, as shown in the figure. This depended on the school schedule, and increased during periods with government programs requiring registration. The peaks produced busy days and excitement among staff members, with queues for photocopying outside the Centre. The typing service took much time for the staff and was provided for a low price, thus giving little surplus, but was regarded as important by staff and customers. The revenue from the TV service in Ikisaya did not cover the costs of operating it, but was kept operating as a social service to the community.

The sale of lanterns or other small solar products did not become important for the Energy Centre business, because very few people could afford the products. Renting was the preferred option. Items that had been meant for sale were increasingly used for renting instead. However, the retail sales later increased through an agent.[85] There was a slightly

[83] It had been expected that the lantern renting in Ikisaya would continue to grow, but the demand mostly got saturated after 14-15 months. The revenue growth during the second year of operation was mainly attributed to the agents (for lantern renting and phone charging), which became the largest source of revenue (around 45%). The next largest contribution was from lantern renting (18%) and phone charging (14%) at the Energy Centre itself.
[84] The efficiency here is defined as the percentage of monthly revenue generated from lantern renting to the maximum potential revenue that could be generated if all the lanterns were rented out in a given month.
[85] The revenue from sale of lanterns (the upper revenue stream in the figure), is artificial in the sense that the whole retail price is included, not only the net profit for each product sold.

downwards trend in most services in Ikisaya from 2013 to 2014, and the reason for this is not yet known.[86]

The main underlying reasons for these revenue trends for Ikisaya Energy Centre were the seasonal variations in the economic situation of the users and potential users of the services, the ability of the Energy Centre staff and agents to enforce the rules of two-day renting and punctual payment, the level of accountability of the agents, and the variations in the need for photocopying. The seasonal fluctuation affected the lantern renting in Ikisaya. There was a reduction of around ten lanterns (20%) or more towards the end of the dry season when many people had problems purchasing even food. Repeated crop failures due to failed rains influenced the situation in a similar way. Also the start of the rains tended to reduce the lantern renting and lead to extra delays in handing in lanterns. This was due to flooded or very muddy roads, a large workload in ploughing, sowing, and weeding, and need for investment in seeds and labor.[87] The revenue of the Centre and its agents was also affected by the level of trust and honesty between the involved actors. Specific staff members took responsibility for accurate and honest handling of money, writing of receipts and use of the safe, which were sensitive areas where control was sometimes difficult.

The staff, board and project team tried out a range of changes in order to increase the revenue and reach out to additional people, in addition to the early and major change of starting the agents and sub-centres in neighboring villages. The staff discovered that haircutting with an electric shaving machine would be possible within the existing power generation capacity, and this gave a revenue of about 2000 Ksh per month. Sale of envelopes, birth certificates and school leaving certificates gave a few hundred shillings per month. The prices for watching television news on TV and for typing were reduced in order to meet people's requests for lower prices and get more customers, and children were permitted to carry the lanterns on the way to school and back to make the renting easier for the families.

Additional equipment was purchased by the project team in order to facilitate enough surplus for economic sustainability. During the months after implementation, the team gradually realized that the Centre might have difficulties in becoming economically sustainable with the equipment they had, even if all the 120 lanterns would be rented out and efficiently used. This was due to lack of surplus for some of the services (especially IT and TV). The agents increased the demand for the lantern renting service, and if extra lanterns would be purchased, these could be charged with the existing charging equipment, which had been planned for 240 lanterns. Team members therefore mentioned for the local actors that the project may do a second round of investment in lanterns and perhaps some lantern charging equipment if needed. They also suggested that the efficiency in lantern renting should be improved first. Some team members were concerned that adding equipment at a time before the Centre had reached a better level of performance could lead to attitudes of dependency among the local actors. The team later agreed that the extra investments had strengthened the chances for the Ikisaya Energy Centre to become independent, due to the

[86] The project team's own use of the services during visits gave a few thousand extra of revenue for the Energy Centre for some of the months of the first year (approximately 15,000 Ksh).
[87] People were at the same time relieved from the burden of walking to the Ikisaya market for water. During parts of the rainy season there were also school holidays so that the children were not frequenting the Ikisaya market.

agent model, which had low expenses and low investment costs. The total number of lanterns actually used after two years was 213, still a low number, and the main reason seemed to be the price of renting, as will be explained.

8.1.4.2. Expenditure trends

As the revenue increased, the average expenditure also increased over the first two years. Figure 18 below shows the expenditure trends from October 2012 to March 2014, divided on the main types of expenses. The expenditure varied widely, between approximately 30,000 and 60,000 Ksh. Like the revenue, the expenditure growth was also mainly attributed to the agents, due to the commission and salaries paid to them.

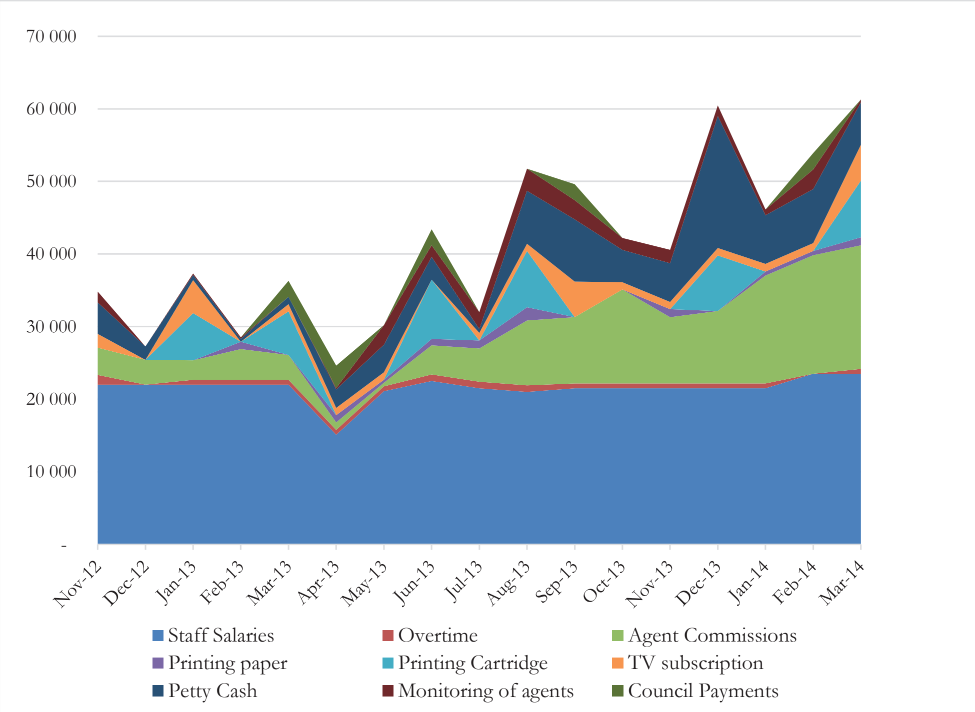

Figure 18. Expenditure trends per type of expense from October 2012 to March 2014 (month 7 to 25). Based on detailed expenditure recorded at the Ikisaya Energy Centre. Figure made by Charles Muchunku.

Because the revenue was lower than expected, there was a dilemma between economic sustainability on the one hand and the salary level and related motivation for the operators on the other hand. It seemed like the staff mostly accepted that the opportunities to get higher salaries depended on their ability to make the Centre work well and utilize the lanterns well so that the revenue would be enough. However, over time, the initial willingness to sacrifice high salaries for the best of the Centre probably diminished to some extent. Salary expenses constituted the largest part of the expenses, and in the early phase, the economic performance improved significantly after the reduction of the staff after seven months.[88]

The costs required to provide the two services of lantern renting and phone charging represented only about 50% of the total expenditure, whereas these two services contributed 70% of the revenue. Therefore, the revenue generated from lantern renting and mobile phone charging subsidized the other services provided at the Centre. One of the significant expenses was to purchase toner for the photocopy-machine every second or third month, contributing to the peaks of the expenses in the figure.[89] Annual expenses such as business licenses to the County Council of Kitui (approximately 17,500 Ksh per year), and the annual auditing (approximately 40,000 Ksh per year) plus transport expenses were higher than anticipated. To the staff's frustration, the County Council fees became high because the council counted each of the three doors at the Centre as separate businesses.

There were many underlying reasons for the expenditure pattern that evolved, including the staff's self-discipline on not using the photocopy machine for activities that did not generate income, as toner and paper was expensive, and how they managed to keep transport costs down. They improved significantly in both of these areas after the early financial reports were analysed and discussed. Another reason for the fluctuating expenses was that the staff at the Energy Centre did some small investments with approval from the board, and these are recorded "petty cash" in the figure.[90] The investments included a counter for the charging room to avoid theft of the customers' phones, extra phone chargers and DVDs to show in the TV room, and furniture for new agents. After two years the total amount for such small investments was at least 20,000 Ksh. It is not known how much the revenue increased by these or other measures for improvement.

8.1.4.3. The challenges of saving for future battery replacements

The key to economic sustainability was the difference between the revenue and the expenses, which was the amount that could be saved for batteries and other maintenance in the future. The graphs in Figure 19 below show the monthly saving, revenue and expenditure for the period from March 2012 to March 2014 (month 1 to 25). The reasons for the fluctuations have been explained above.

[88] The salary expenses were reduced from 30,000 Ksh to 21,500 Ksh.
[89] The price was 7,500 to 9,000 Ksh per cartridge.
[90] Petty cash included, in addition to the small investments, expenses for cleaning soap, water, receipt books, record books, phone cards, paint for the house, etc.

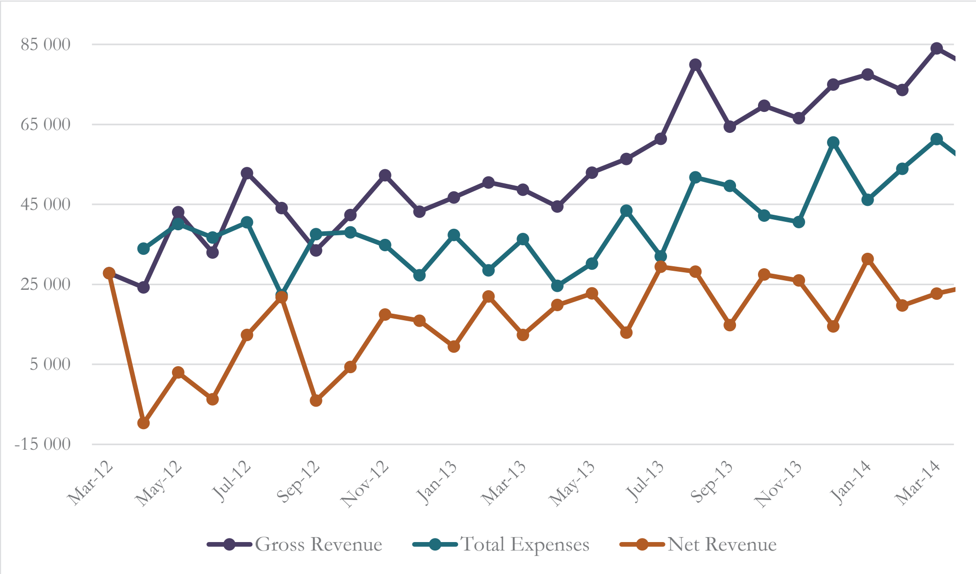

Figure 19. Revenue, expenses and surplus (net revenue) from October 2012 to March 2014 (month 7 to 25). Based on the records of the Ikisaya Energy Centre. Figure made by Charles Muchunku.

The target for the saving of 21,300 Ksh per month was set slightly higher than what might be necessary, to secure sufficient saving, and in case of unexpected breakdowns. From month 7, when the saving started fully, to month 25, the Centre saved an average of 10,600 Ksh per month, i.e. half of the target. So far it is unclear whether this deficit will create problems for the Energy Centre. The total saving by March 2014 should have been 447,300 Ksh[91] whereas the actual saving was approximately 220,000 Ksh.

8.1.4.4. Is the Energy Centre economically sustainable and self-expandable?

After two years of operation, it could still not be claimed for certain that the Energy Centre had become economically self-sustaining, although both operation and maintenance costs had been covered up to that time. It was not yet able to expand on its own. It is a difficult task to define when an organization has achieved economic self-sustenance, due to uncertainty about future expenses. Economic sustainability is not a constant condition, it can increase or decline over time depending on the saving trends. The Energy Centre paid its first large bills during the second year of operation – an amount of 131,000 Ksh for new batteries for the Indian lanterns, and an amount of 80,000 Ksh for replacement of two of the larger batteries at the Energy Centre. This was a total expenditure on maintenance and battery replacement of 211,000 Ksh which equals to an amount of 8,750 Ksh per month during the 17 months that saving had taken place.

[91] This is if the saving had been 21,300 Ksh per month for 21 months, starting after three months of operation.

A factor that unexpectedly came into the picture was that the electricity grid was on the way to Ikisaya. The effects are uncertain, but according to the staff and board, the services of the Centre will still be needed, because very few households and businesses will afford to connect to the grid. Most people also live too far from the gridlines or too far from the transformers. An amount of 200,000 Ksh has to be paid for an additional transformer. The Centre plans to continue with the same services as before, and consider the situation over time.

The grid power might possibly lead to start-up of competing energy centres or charging stations by business actors, so that the Energy Centre might have to change its strategy, or be moved to a place without electricity provision. Importantly, several of the agents of the Centre are in villages that will still not be reached by the grid. The Centre staff have some preliminary ideas for new services that can be offered when they get connected to the grid, which are not possible with their solar power system.[92]

8.1.5. The impact of contextual factors and framework conditions on the system's functioning

The analysis has shown that the local, socio-cultural context of the Ikisaya project played a strong role for how the energy model developed after the start of operation, even stronger than during the planning process. The realities of the potential users now became clearer through the ways in which they actually related to the energy system and how they developed new practices in relation to it. The extreme challenges and constraints in people's everyday life influenced the way in which they used the system. However, the project team's close attention to people's situation during the design process clearly contributed to the suitability of the system for the users.

The national framework conditions did not have a direct impact on the functioning or changes of the energy system in Ikisaya so far, except for the uncertainty created by the unexpected grid extension. However, these have importance for replication and up-scaling, as will be explained. The Sunderban cases were more influenced by national policies than the Ikisaya project. This was due to a more active policy in this field in India, due to the longer time span of the projects, and because the project implementer in the Sunderban case was a government agency.

8.2. Resulting access to electricity services

This section describes and discusses the most important purpose and end result of the socio-technical learning process – the actual access to electricity for different groups in Ikisaya and surrounding villages, including the qualities of the access, such as affordability and other qualities that determine the availability for potential users (dimension E of the case study framework). The analysis continues to focus on how socio-technical innovations can become

[92] These include hair-saloon for women, which has been asked for by community members. The women said they would like to look as good as the city women.

well integrated and embedded in societal contexts in specific places and countries and what kinds of factors might influence such processes of "contextualization".

The first level of energy access defined by the UN, "basic human needs", includes electricity for light, education, health, communication and community services in places where there is no or minimal access to electricity services (see Chapter 3). The pressing question is *how* this can be done, and the Indian and Kenyan cases have demonstrated the complexities of this question. The case study in India showed great variation in community members' ability to utilize the services – depending on the system design and how it suited people's needs, economy, gender, and spatial location of their homestead. The following analysis identifies the users of the Energy Centre services, which services they used and when, and which factors influenced people's opportunities to use the services, thus showing the users' perspectives on the Ikisaya project.

The long-term impacts of the electricity services on the community members' economy, livelihoods and quality of life do not form part of this analysis. Rather, the analysis concerns people's ability to use the services, and whether they find the services interesting enough to prioritize within limited economic resources. Spatial, economic, technical and other factors that influence people's opportunities to use the services are discussed.

8.2.1. The actual use of the electricity services

The kinds of users and their ways of using the electricity services in Ikisaya and surrounding villages varied between the different villages involved: Ikisaya, Endau town, Malalani, Yiuku, Kathua and Ndovoini (see the map in Chapter 7). The kinds of data collected also varied between the places, because the initial focus was on the Energy Centre itself and the Endau agent. Some agents were installed after the main data collection.

The focus is here on provision of light, since this was found to be a difficult service to provide broadly, in a way that would enhance the use of electric light on a daily, or nearly daily basis. Phone charging, which is done at the same price at various charging points all over Kenya, was a simpler service to provide, both economically, operationally and organizationally. Features of the IT and TV services will only be briefly touched upon below, as these were also less complicated organizationally than provision of light. The 213 lanterns used in May 2014 were distributed as follows: Ikisaya – 47, Malalani – 32, Endau – 65, Ndovoini – 7, Kathua – 17, and Yiuku – 45.

An interesting aspect of access to electric light is the distribution of users between households and businesses. Households tend to have more difficulties obtaining electricity services than businesses because they are more financially constrained. Among the lantern renting customers of the Ikisaya Energy Centre and its sub-centres, the portions of households and businesses varied. The distinction between a household and a business was often not straightforward, because people might do business at home. The businesses operating on an everyday basis had a regular cash-flow, they were located near the electricity provision and they had a larger potential to save money by switching from a kerosene lamp to an electric lamp. Furthermore, they had the largest potential to increase their income through the use of electric light.

The following sections discuss factors that influenced people's ability to use the services, and how the services could be improved to fit better to people's situation.

8.2.2. The role of geographical distance to the power supply

It is still unclear what an acceptable walking distance is in this area and how many people live within such a distance of the renting services. According to the local knowledge of the staff and their familiarity with their lantern renting customers, the walking distances of the customers are mostly within the range of 50 meters to four kilometres. Some people walk extremely far to get water, up to 8-10 km, as mentioned in Chapter 7, but most people walk shorter. The realistic walking distance is likely to be related to the borders of the school enrolment, since the children often carry the lanterns. Walking distances for each of the customers are yet to be checked accurately with GPS receivers.

The geographical distance from the power plant to people's homes was clearly a limiting factor for parts of the population in the Sunderban villages, and it also played a role in Ikisaya, yet in a different way. The dispersed settlement pattern contributed to the Energy Centre approach, as explained in Chapter 7, since this kind of model did not have an absolute limit for its outreach. The challenge of long walking distances was reported to be solvable in different ways in Ikisaya, by combining errands, but there was still a limit for the outreach.

Some of the six sub-villages of Ikisaya, especially Ndovoini and Kalwa, were too far away to be reached by the Energy Centre, and the children there attended a primary school in Ndovoini. They could therefore not carry lanterns from the Energy Centre for their family. An agent was established in order to reach out to these most remote areas of Ikisaya, first in Kalwa, thereafter moved to Ndovoini[93], but it got only 7-8 lantern customers, and these used the lanterns more sporadically than people in the other villages. The reason was probably that people could not afford to use the lanterns, as the poverty here was especially high.

A few customers (including two schools and a health clinic in Endau Town) rented a lantern with a panel so that they could charge on the spot. A few households in remote places were also given this opportunity, but it was a challenge for the Centre to collect money from people who were not visiting regularly. A small portion of the households could be able to purchase their own, small solar lantern, but those who had purchased lanterns at the Centre had problems in paying all the instalments.

Some of the other services offered at Ikisaya Energy Centre, especially the IT services, were used by customers from a wider area than the lantern charging services because people needed them more sporadically. The Centre was the nearest entity where IT services were provided for people in a wide area.[94] Customers expressed that they appreciated the availability of IT services in Ikisaya, which saved them time and money on travelling further away for typing and photocopying.

[93] The agent was moved from Kalwa to Ndovoini in 2013 due to dishonesty by the agent in recording revenue.

[94] It was the nearest option for the villages Ikisaya, Malalani, Twambui, Damsau, Kalwa, Ndovoini, etc.

8.2.3. Affordability and other considerations for users

Despite challenges of geographical distance, it appears that affordability was the most central issue for the pattern of lantern renting. In a public meeting at the Energy Centre after five months of operations, most of the questions from community members were about the price. However, neither the staff, board nor the team members saw it as desirable or possible to reduce the price at that time when the Centre was struggling to build up its revenue. As the Indian case showed there was a dilemma between affordability and usefulness of the services on the one hand, and economic sustainability on the other.

It became clear that many of the community members in Ikisaya as well as the villages where the agents operate could not afford to rent lanterns regularly, or at all. Those people who could not afford to use any kerosene or torches, or very little, could not afford to use the lanterns regularly either. They might choose to use them for some of the time, like some of the customers in Ndovoini and Ikisaya.

The rule about flexible renting – without obligation to subscribe to a fixed pattern of payment and use appeared to be important. Renting for only 1-2 times per week was observed for many of the customers, especially during the first months. Thus, they had a renting pattern that could be expected according to the focus group interviews before implementation. However, they did it in their own way, by keeping the lantern at home in between the 1-2 times per week when they came to the Centre, also if there was no power left in its battery. This practice did not have only economic reasons since some established such a practice even though they could afford to spend 20 Ksh every second day on lighting, but the need to save on the expenditure was important. Later, when the staff managed to make the customers follow the rules of renting the lanterns for two days at a time, some of the customers started to take breaks from renting (1-3 days every time, mostly), because they could not afford to rent every second day.

Despite the problems of affordability, the portion of households reached by the lantern renting was higher in each village (especially Ikisaya) than the average figures for solar home systems and lanterns as well as connections to existing gridlines in rural areas in Kenya. In Ikisaya sub-location (incl. Ndovoini) about 17.6% of the total number of households had been reached in May 2014. Of those that were within the practical walking distances for lantern renting as reported by the staff (four kilometres) about 30% were using the lanterns, but this figure has to be checked further.

In August 2014 the board decided to reduce the price after initiative from the team leader and the Energy Centre staff. It appeared to be a difficult decision to make, because of the uncertainty of the effects on the Centre's economic performance. After three months of lower price, 15 Ksh instead of 20 Ksh, the staff reported that a small increase in the lantern renting had been observed, and the revenue showed a slightly increasing trend after the initial drop when the 25% price reduction was implemented. However, the revenue was still lower than before the price reduction.

Both in the Indian and the Kenyan case the services were cheap for many of the local businesses. By keeping the prices low for the sake of the households the implementers subsidized the use of the services for the businesses. If the businesses had paid a higher price than the households, they could have improved the economic performance of the systems. The kerosene-expenditure of some of the businesses in Endau had been up to 40 Ksh per night, while the use of an electric lantern costed them 10 Ksh per night. On the positive side, this probably helped strengthening income generation for these small, marginal businesses, assisting the involved families. It might also contribute to a larger circulation of money locally. Nevertheless, such effects could have been possible also if businesses paid slightly more. The challenge of having different tariffs would be the difficulty in distinguishing between business and household, explained above.

8.2.4. Quality of the services and users' satisfaction

Part of making lighting services fit in the social context is to make them fit with people's daily activities. A simple survey carried out at Ikisaya Energy Centre in May and June 2014 (by the staff) gave a glimpse of how the electric light plays a role in everyday life, and indicates that the portable lanterns meet a need for flexibility in where and when to use the light.

The survey covered the households and businesses who rented lanterns in Ikisaya during this period, on varying days, often represented by school children. Eight of the 47 customers were small businesses. Most of the businesses in Ikisaya that needed light in the evening rented the lanterns. The school and the private nurse also used the lighting services. The rest of the customers in Ikisaya were households. The staff at the Centre asked the customers three questions; who had used the lantern for the last two days, for what, and where. The results showed that the light was used by different family members for a variety of purposes. It was common to use the lantern for business and household chores interchangeably. The activities were related to health, education, income generation, livelihoods, safety and general improvement of quality of life.

Common answers were that the mothers had used the lantern for cooking, washing clothes, and washing utensils. One mother had used the lantern to read her notes for her education to become a teacher, another for university studies. Mothers had also used the light when knitting baskets and tailoring. Grandmothers had used it when grinding millet or milking cows. Children had used the lantern when doing homework or when playing. Some fathers had used the lantern in repair work, handicraft or carpentry (e.g. repairing the bicycles' tire, repairing the table, making his machine for cutting timber, and making mats for sale). A father had also used it for measuring the sugar and cooking fat in his shop, another when searching for cattle, watering plants at night or carrying the harvest home. Parents or grandparents used it in teaching their children or taking care of a baby, and when spreading their bed, (probably in order to check for dangerous insects). One family had used the lantern to kill a snake that was trying to enter their room. Some used the light for reading the newspaper or the bible, and teachers used it for marking exams and preparing the next day. It was common among women to use the light for business in addition to housework, and some used it when walking home after dark. These examples illustrate that the lanterns gave flexible lighting compatible with a variety of use areas.

Both women and men were actively involved in renting lanterns. A statistical analysis of the daily records of the agent in the village Endau town from April 2012 to March 2013 examined the gender distribution of the customers. Among the 55 persons who had registered for lantern renting in Endau town, 20 were men (36%) and 35 were women (64%). Women were also in majority among those who actually came to rent the lanterns. Several family members might have used the lantern in the evening, as the data from Ikisaya suggest, but the analysis from Endau indicates that women found the service useful and possible to use. The user survey in Ikisaya mentioned above also strongly supported that women used the lanterns. The lantern renting service seemed to be a suitable solution for both genders, as well as for different age groups.

The users' satisfaction with the services in general seemed to be good. The fact that people prioritized the payment for these services showed that they found them important and useful and better and/or cheaper than existing alternatives. Moreover, the Indian lantern used in Ikisaya, which had been developed in close communication with users in remote villages in India, was robust, gave good light and had a shape that made it easy to carry it around and place it anywhere. According to the chairman of the CBO, the lantern renting customers said that "we only want the bright light now – we don't want the dark light anymore." The bright light referred to the light from the electric lanterns and the dark light referred to the light from kerosene lamps. The staff did not report complaints about the quality and the duration of the light from the lanterns other than during the waiting time for the delivery of new lantern batteries.

8.2.5. The opportunity for new users to get access

A challenge in the Sunderban was that new users could hardly get access after the capacity of the power plant was saturated. This might also possibly happen in the Ikisaya system with its associated agents. If demand increases and the Energy Centre does not become strong enough to expand on its own in the long-term perceptive, lack of capacity might be the result. There will be need for investment in additional equipment. An advantage of the Energy Centre model is that gradual expansion is easier with this model than with a micro/mini-grid, because of the more modular nature of the technical installations. A few lanterns can be purchased at a time, or a charging box, or a solar panel, as long as this is available in the country. Relevant equipment had become available in Kenya by 2014, while some could be purchased efficiently from China.

The coming electricity grid will provide alternative options for some families, and perhaps some will thereby be able to use electricity for other purposes than the ones that the project team chose to include in the Energy Centre design. Some "productive uses" might occur when the electricity grid becomes available.

8.3. Main factors influencing the functioning and qualities of the Ikisaya system

As mentioned in Chapter 6, the main guiding principles or objectives for the Solar Transitions team in Kenya had been to develop a model for village level electricity provision that would give 1) Broad access to the electricity services, 2) Economic sustainability and expandability, 3) Well functioning operation and maintenance (including technical robustness), 4) Gender and context sensitive planning, implementation and operation, 5) Modest investment level, and 6) Replicable/scalable system. The chapter has shown that these were only partially achieved, for reasons explained above and summarized here below, and it is too early to say whether the Ikisaya project is viable in a long-term perspective. Interestingly, some of the conclusions on the Kenyan case have similarities with the conclusions on the Indian case, despite the significant differences between the two models as well as between the planning and implementation processes involved.

The analysis has shown that a range of details played a role for how the system functioned, how it provided access to electricity, and for what, to whom, where and when. The involved actors learned about these details (both social and technical) by dealing with the system in practice over time, struggling to solve problems that occurred, in the specific geographical and socio-cultural context of the system. Although the team identified and took into account important contextual factors during the research and design phase, the actual implementation and operation (and continuous research) strongly increased the understanding of how the context influenced the system. The practical experience demonstrated how the details of the system could be further developed in order to suit better with the socio-cultural context, especially people's economic situations, their daily practices and walking distances. People's practices also changed in the process.

The local power provision created in Ikisaya and surrounding villages provided relatively broad access to basic electricity services, like the Sunderban projects also did, although far from access to all. Like in the Sunderban, the project achieved broader access than other solutions for provision of electricity services often do in remote areas with high levels of poverty and dispersed settlement patterns, yet not as broad as the team had aimed for. As suggested by Wong (2012), renting and fee for service solutions reached a much larger portion of the population than those that could afford to purchase lanterns in Ikisaya.

The local infrastructure gradually became something that many people in Ikisaya did not want to lose. The opportunity to get a photocopy of an important form without travelling to other places for instance, even though this opportunity might be used only a few times in a year, had a value for community members. A kind of social pressure developed towards the responsible people to keep the system going, and this seemed to be part of the staff's motivation.

The Centre became relatively well-functioning in operation and maintenance due to the staff's level of commitment, and complementary areas of interest for the different staff members (technical tasks, service delivery, communication with community members, leadership, etc.). The leadership style and cooperation among staff members, as well as the way they trained new staff members appeared to be important for the functioning, in addition to the way in which the team followed up the project. However, some of the challenges met by the Centre for becoming independent could have been better met by slightly more presence by the project implementers in addition to brief visits and phone calls only.

The freedom of the staff to influence the system was a characteristic of the socio-technical design. They had the freedom to be innovative and try out new ideas for improvement (with approval of the board), and were encouraged to do so, although some attempts failed, as must be expected according to theories on socio-technical change. Compared with the Sunderban projects, the staff/operators in Ikisaya had more freedom to make improvements and be creative, but they also had more responsibility and had to take more risks. The board also influenced the system to some extent, through its impact on the staff's activities, but remained passive and had potential to have a larger impact. A task for the project team would be to find ways of addressing this problem.

Despite the attempts of the team and local actors to create good organizational structures, the chapter has shown that the specific persons involved in the activity had a strong impact on the functioning of the Energy Centre, including project team members, staff members, board members and community leaders. A similar picture was seen in the Sunderban case. Commitment, honesty, skills and ability to cooperate were important characteristics of those persons that came to play important roles, and the enjoyment of the job or role was also crucial.

A positive side of the long-term concern and pressure to achieve economic sustainability was that it gave incentives to the involved people for applying business principles, being creative and to make improvements. A negative side of this was that goals for economic performance became stronger than the goal for reaching as many people as possible in each place, but the economic constraints nevertheless made it difficult to reduce the price to reach more people in each place.

The model was trust-based, because it could not be possible (or desirable) for project implementers to control the actions of local actors other than through analysis of records, and public audits. The model seemed to be dependent on having two or three key individuals with personal commitment and an honest attitude, and at the Energy Centre, women were especially important for this. At the agents, the commitment and attitude varied for both genders. Although there were economic incentives in that the salaries could be increased if the Centre performed well, this did not seem to be the strongest motivation for the most committed persons.

Regarding economic sustainability, a range of underlying issues and aspects of the system were found to affect this in the case of Ikisaya Energy Centre, including the following:

- The suitability of the services for the daily practices of the community members
- The affordability of the services.
- The suitability of the rules for the users of services.
- The practices and ideas developed by the users.
- The staffs' ways of doing their jobs: their cooperation, leadership style, degree of honesty and way of communicating with the customers.
- The board and executive officers' ways of taking on responsibility and cooperating with the staff.

The dynamic interaction between a range of system elements thereby influenced the economic performance. The portable lanterns suited with peoples everyday practices because they met people's needs for moving around with the lights, illustrating the importance of developing socially embedded energy systems. At the same time, the system also required the establishment of new practices among the users, due to the batteries' need for frequent charging. The Energy Centre's chance to achieve economic sustainability was thereby affected by the extent to which people were able to follow the rules for delivering and picking up the lanterns at the right times. This again depended on the extent to which it was possible to set, and not least implement, rules that could suit for people within their daily rhythm, workload and livelihood struggle. The rules were not optimal for the users because they were set within the limitations of the technology. The sensitivity of the batteries, like in the Sunderban case, thereby influenced a range of other, non-technical aspects, including the rules for the use of electricity, the quality of the services, the convenience for the users, and challenges for operators, in addition to economic performance.

Similarly as in the Sunderban, the users responded to the provision of electricity services in ways that were not anticipated by the implementing actors. Such challenges were both a source of frustration and a source of learning in both projects. The practices developed by the users contributed to different systems than those that were planned, as suggested by theories on users' appropriation of technology and development of new practices as part of socio-technical change (Sørensen 2013). In the Ikisaya case, a challenge was to find a balance between enforcing rules and adapting rules to the users' preferences and practices.

Interestingly, the relevance of community involvement in the planning of projects which is often suggested in the literature on village-level projects (Ahlborg and Sjöstedt 2015), differed between the Energy Centre and the agent "stations". Opening an agent in a new place was a business-like and simple task. In Ikisaya, community participation (i.e. involvement of potential users) was experienced as useful first and foremost for the development of the ideas for the Energy Centre Model. It was less useful for making the Centre function smoothly in the daily operation. People in Ikisaya, who had been encouraged to give their views during the planning phase were less willing to accept the rules and prices after implementation than customers for the agents' services in some of the surrounding villages. The collective discussions in Ikisaya on budgets, prices and rules before start-up might have given community members a feeling that they could have a strong impact on similar considerations also later. The intention was also that they were going to have an impact, but the economic and technological limitations had to be taken into account. The community members now gave their opinions through the way they related to the Energy Centre staff and the way they used the services. This gave the staff some challenges and led to loss of revenue because it was difficult to fulfill the needs and wishes of the users. However, the community members' feedback was still an important source of learning on how the services could be adjusted to the users' situation.

The chapter has shown how the different dimensions presented in the framework of analysis interacted in the case of Ikisaya. Despite the importance of changes after implementation, the outcomes of the project were strongly influenced by the socio-technical design that had been developed before start-up. To a large extent, this defined the actors' opportunities after implementation. The design nevertheless gave some freedom to the involved actors, because it had some inherent flexibility. It was possible to start the agent system, make price adjustments, change styles of leadership and cooperation, start phone charging in new places, start haircutting, develop new ways of explaining to the customers, and staff training young women on IT, charging and book-keeping. The flexibility was first and foremost made up by the modular nature of the lantern charging systems developed in India, as well as the modular nature of the solar PV technology in general. It was relatively easy to dismount and transport solar panels to other places. Moreover, flexibility was made up by the willingness of the project implementers to make changes, and support the local actors' ideas for changes.

8.4. Observed replication and potential replicability

A desired consequence of demonstration and pilot projects (or socio-technical experiments) like the one in Ikisaya is that they can be more widely used (be replicated or up-scaled) or at least generate some inspiration and learning for new efforts for social and technological change (Brown et al. 2003). If the Ikisaya model or parts of it could be implemented widely, it could potentially contribute to solving some of the challenges of electricity access for people in dispersed settlements common in the dryland areas of Eastern Africa and other parts of Africa. It could also be suitable in villages with dense settlements, in fact even more suitable there due to shorter walking distances for the users.

Some of the aspects of the Ikisaya Energy Centre model are likely to be possible to build on by others, in similar ways as the Ikisaya project took ideas from other models and mixed them with knowledge on the contextual factors and the views of the future users, and learned through trying out socio-technical designs in practice. One attempt of building on elements of the Ikisaya model was initiated by the government contact of the project team. He wished to take elements from the Ikisaya design to develop a model that could be up-scalable within the government's organizational and policy framework. The team supported this initiative and participated in it.

The "new" model had many similarities to the agents around Ikisaya Energy Centre, and was a significantly simpler kind of system than the Energy Centre, although it still provided two of the most important services; lantern renting and phone charging. The investment costs were significantly reduced through using a pure "agent model", because the only investment needed was for solar PV equipment for lantern charging and mobile phone charging. Some cost recovery and ability to expand by use of the revenue could thereby be achieved, in addition to covering the costs for operation and maintenance. Agents were started in existing buildings in the market areas of different villages with existing business people. These projects were gradually implemented in different villages in Turkana County and later in other counties (20 agents in total as per December 2014.) They were coordinated by the government official in Nairobi as a voluntary/spare time activity. He was responsible for revenue collection to a project account for maintenance and expansion, as well as follow-up by phone and visits. The project covered most of the travel costs. In the case of Ikisaya the coordination of agents was taken care of by the Centre staff, as part of their job.

Small scale private sector actors from Germany, Japan and China took some inspiration from this (including the Ikisaya project) in their work to develop and manufacture equipment that could help making a streamlined and minimized charging station model which could become profitable. They worked on solutions for remote monitoring of the agents' transactions and systems for pre-payment. The team tried out their different equipment and gave feedback. The Kenyan government official worked with a Chinese company to develop one type of a prepaid charger. Through his pilot projects he found this "Chinese system" to be best, and the team ordered some also for expansion around Ikisaya. These were produced in China on order, as the team was the only buyer of these chargers so far.

Some qualities of the Ikisaya model got lost underway, as tends to be the case during the up-scaling of pioneering sustainability projects (Seyfang and Smith 2007). One detail that was not transferred to the new agent projects, for instance, was the flexibility for the customers in lantern renting. Such flexibility enhanced affordability, but reduced revenue. During the team's considerations on the new agent model, much weight was put on economic performance, partly based on the struggle for economic sustainability in Ikisaya. The team decided that the new agents had to pay a fixed amount per month to the project owner according to how many lanterns he or she operated. This in turn made the agent to request for fixed monthly payment from the customers, 20 Ksh every second day, 300 Ksh per month. The agents and the project implementer thereby collected a higher revenue per lantern than the Ikisaya system, but at the same time excluded those people who could not afford the fixed amount every month. The team's attempts of asking the agents to give the customers flexibility did not lead to results. Other qualities also got lost, including provision of IT services, and development of a variety of skills among several people who were involved as staff and board members.

When starting the above mentioned agents in Turkana and other counties, the government official already knew that the government was going to receive a grant from a donor, Nordic Development Fund (NDF), which could be used for a larger activity.[95] He had been central in securing this grant, also here supported by the ideas obtained in India. The pilot projects on the gradually improved charging station model or "agent model" built a bridge from the initial Ikisaya project (and the Indian solar charging stations) to the larger grant-funded activity, because it allowed for some necessary experimentation with a gradually increasing, but still low number of agents. It was important for the responsible person to be able to do his own pilot projects on this model and try out different details of the socio-technical designs instead of just participating in the Ikisaya project. He tried out different kinds of charging devices and types of lanterns, different kinds of agreements with the agents, routines for revenue collection, and different procedures for identification and training of agents. The model became gradually more standardized, with some small variations. This work was likely to be an important preparation for the coming, larger activity because it allowed learning on what it might mean to manage a number of agents in different places far from where the coordinator is located.

[95] The grant included support for several kinds of renewable energy installations for power provision, especially in the isolated power grids fueled by diesel.

These effects of the project were partly based on "good luck" in terms of the government official who caught interest in the work. Through his participation, the team thereby got a link to higher level policies as suggested by Seyfang and Smith (2007). It was, however, important that the government official participated based on his own personal interest and initiative. This person was a regime actor that caught interest in a niche technology and thereby became a kind of "hybrid actor" who was able to use his deep knowledge about the electricity sector in Kenya and combine it with new knowledge about new technological options. It was not easy for him to go as far as he wanted within the established government structures, but he achieved to get accept for some of his ideas, including upcoming donor funded implementation of 840 solar charging stations. The NDF grant made the government's energy organizations to accept a new kind of activity for them, initiated from an insider, based on practical experience from the above mentioned pilot projects. In addition, as mentioned in Chapter 6, the general trends of solar PV technology including price reduction, large installations worldwide, and interest from donors to support "clean energy" also most likely contributed to creating the changing ways of viewing the technology at the national level in Kenya.

The government official used the information from the visit in India to present solar PV in a way that appeared to be more interesting for important "regime" policy makers than previous solar PV installations in Kenya. Although solar PV continued to be a small activity for the Ministry of Energy, Kenya Power and the Rural Electrification Authority in Kenya, it became a normal part of their work on isolated power grids. Mr. Choudhury, who was the driving force for the Sunderban mini-grids told the team in 2010 that he and his colleagues had "burned their fingers" on the problems met. However, they inspired new activities including those in Kenya, making the above mentioned government official say (in March 2015) that "solar has become part of life now". He pointed out that power generation from solar PV (and wind) featured in the statistics for the first time. This was achieved through "hybridization" of existing diesel mini-grids (the "isolated power grids") by introducing solar PV to reduce fuel costs, as explained in Chapter 6. One individual contributed to "empowering" the solar PV sector (or niche) in Kenya (Smith and Raven 2012). He managed to get acceptance for new activities and probably contributed to changing powerful actor's ways of viewing solar PV technology, slightly. (One could also call it "institutional work" as defined by Fuenfschilling and Truffer (2014).)

In addition to these attempts of replication, some learning diffused from the project through the team's spreading of information about the results in Ikisaya to other project teams, NGOs, aid agencies, companies and government actors. Three team members (in addition to the above mentioned government official) were also sometimes involved in policy advice and discussions in Kenya, and could give inputs on future possibilities for policy and practice. The team organized workshops in Kenya, India and Norway, made a film about the Ikisaya project at an early stage, and a report for practitioners (Muchunku et al. 2014), in addition to academic papers on the Sunderban and Ikisaya cases. Three team members visited the Department of Renewable Energy at the Ministry of Energy in Kenya and presented results. Officials from Kenya Power and Rural Electrification Authority attended. Team members also shared information in workshops organized by others, in India, Italy, Germany, France, UK, South Africa and USA, and wrote short articles. The effects of these activities have mostly not been possible to track, although some actors have expressed interest, and although it is likely that some receivers of the information have gotten some new ideas and information that they could use. Some of these organizations travelled to Ikisaya and visited the Energy Centre and received information from the staff there.

The learning for the project team members themselves, including the new knowledge, ideas and inspiration that each of the involved people acquired underway, were also among the observed consequences of the project. This learning would probably influence future activities in places and countries where team members operate. Other extended effects were new networks and collaborations on business, project proposals, and other activities between renewable energy experts within and outside Kenya, according to team members. For instance, the Indian team member developed new projects in Africa in cooperation with Kenyan team members, and a Norwegian team member developed a new academic project (on women and energy) in cooperation with Indian and Kenyan team members. There was also an observed, ongoing spread of ideas at the local level in Ikisaya and surrounding villages, especially since the local staff trained new persons on their own.

In addition to the observed learning outwards from the Ikisaya project, the "replicability" of the Ikisaya model itself should be discussed in terms of the possibilities to implement similar models in large numbers (with necessary adaptations to local context). The Ikisaya model with surrounding agents is a much more complex model than the agent model described above, because it is a separate business unit that offers several different services and manages several agents. An important question is also who could potentially implement similar models in large numbers. However, the planning and implementation of follow-up projects would be simpler than the pioneering, explorative transfer process.

It is not possible for a poor, remote village to replicate the Ikisaya type of model on their own, although the project has low investment costs compared to other options for provision of basic electricity services to off-grid communities. Investment support from government, NGOs, funding agencies or others is required. Significant assistance is also likely to be necessary during the implementation process, and follow-up and advice is required after implementation.

The team had intended and expected to develop a model that could be widely used, but the expectations seemed to be lowered based on the Ikisaya experience. Team members questioned the possibility to replicate an important characteristic of the Ikisaya model. This was the way of following up local actors. Other project implementers might not be able to take time for this or might not do it with similar commitment. It is uncertain whether the follow-up was at a low or high level since there are few examples to compare with in the literature, but as mentioned earlier in this chapter, it was probably relatively low. In hindsight it might be said that slightly more follow-up could have been useful both for the staff and the board. In other future cases, one could imagine that some kinds of organizations (i.e. project implementers) could have the possibility to have a full-time person, for instance a "field officer" who could follow up a large number of local units. Individuals like the key staff members in Ikisaya, for instance, acquired skills that made them suited for such tasks.

The project analyzed by Ahlborg and Sjöstedt (2015), which was larger and more complicated, was followed up intensively, having a person from the implementing agency present in the village constantly, only leaving the village during the weekends, for the first 4 years.[96] Compared with this example, even though the projects were different, the follow-up for Ikisaya was very little. The total number of days when the Ikisaya Centre had visitors from the implementing project team during the first two years of operation was less than 30. The time spent on phone calls was approximately 80 hours during the first two years, most of the times on initiative from the project team members, not from the local actors, and partly for the purpose of data collection.

Widespread implementation of the Ikisaya type of model is likely to depend on the kinds of actors involved, not only the characteristics of the model. For government organizations it could be possible to start similar projects if there was political willingness and interest for such a way of providing electricity as a complement to grid extension. In the case of Ikisaya, officials within the Kenyan Ministry of Energy and Petroleum, Rural Electrification Authority and Kenya Power had earlier expressed interest in the solar mini-grids that the team studied in India. They also showed some interest for the Ikisaya Energy Centre model when the team presented the Ikisaya experience for them before and after implementation in 2012, although it did not become a mini-grid. However, they also said that investments in such projects by them would depend on the demonstration of strong models that could generate a financial surplus. The surplus should then be used for similar projects in new places, in similar ways as the tariffs paid by grid connected customers in Kenya contribute to investments in un-electrified areas. Thus, they would demand a strong economic performance where the village project not only managed to cover its own operation and maintenance costs but also gave a surplus. The existing policies and regulations in the electricity sector here affected the thinking about replication of an alternative kind of model. However, the government officials did not express any real wish to start working on such models. They later accepted to implement the "agent model" mentioned above, but coordination and follow-up of operation and maintenance was going to be tendered out, following typical government procedures. They seemed to view it as a one-time activity which would continue by itself once it had been started.

Private sector actors could potentially implement village-level power supply, but the Ikisaya model is not likely to be interesting for them because of the upfront investment required (42,000 Euros in this case) and the lack of profitability. As mentioned in Muchunku et al. (2014)[97], businesses could generate quicker and higher returns elsewhere. A capital subsidy for the purchase of equipment would therefore be needed if a similar model is to be replicated. Nevertheless, the components of the model being tried out in Turkana and elsewhere for lantern and phone charging could possibly be interesting for private sector investment since it requires less than one third of the investment costs.

Civil society actors, such as NGOs, might be able and willing to take up many of the characteristics of the Ikisaya model. Organizations who have knowledge and experience from cooperation with village communities on various kinds of projects would be able to achieve

[96] This was a micro-hydro project.
[97] This is the team's report for practitioners about the Ikisaya Energy Centre Model.

good results with such a community operated model, which is more complex, but also more rewarding than a simple agent model. NGOs might be able to facilitate similar kinds of learning processes as seen in this chapter, care about the details, put emphasis on women's roles and adaptation to local context. They can be able to emphasize the human dimensions of socio-technical change and work on the difficulties in providing affordable and accessible services. Research institutions could be able to be involved in similar ways, depending on their time and resources for doing so.

Such civil society activities would depend on a capital subsidy and other funding, but economic sustainability could be possible. The Ikisaya project has shown which parts of the technical installations could be scaled down to reduce maintenance costs. One organization could implement a suitable number of projects according to their capacity. A framework for quality control should be part of funding programs. However, the current funding programs are limited and many good project ideas by serious organizations are not funded. Some of the international initiatives for funding of climate and energy related work could be allocated to non-commercial power provision through civil society actors.

There are few specific barriers for the implementation of village-level electricity systems in Kenya created by government regulations or lack of such. Many of the challenges for implementing actors and local operators are related to the details of the socio-technical configurations and the need to provide funding for the initial investment in non-commercial social services, as well as the funding and organization of widespread implementation. However, there is also little or no facilitation for initiatives to implement village-level electricity systems. The lack of funding support and other kinds of facilitation from the government can be seen as a barrier for widespread implementation of village-level, community operated electricity provision, but it is also understandable that the government is not active in this regard. There are large challenges in conventional power provision, and government actors are under strong pressure to implement large scale solutions fast.

Chapter 9: Conclusions

This dissertation has sought to contribute to new knowledge on how to achieve basic electricity access to all and how socio-technical innovations can be transferred between places and countries. The work has been inspired both by the abundance of solar energy that is available in most places where electricity access is lacking, and by the future oriented activities already going on in the South in relation to the use of renewable energy technologies. Pioneering infrastructures for provision of electricity at the village-level represent radical socio-technical innovations with a large potential, but it is not yet clear how this potential can be turned into actual access to electricity for a large number of people. Such cases have therefore been selected as well as created through this research, and a process of South-South transfer through South-South-North learning has been explored and analyzed.

Two mutually supporting levels of research run through this dissertation. The first is research on the social organization of village-level electricity provision, and the second is research on the spatial and socio-cultural transfer of socio-technical innovations. The investigation of how local infrastructures for electricity supply can be organized in their societal context has been important in order to understand spatial transfer of innovations. This is because the village case studies provided understanding of the phenomena that the involved actors attempted to transfer between different places in different countries. The case studies have also shown what kinds of outcomes the transfer process led to. This has helped to understand what kinds of knowledge and experience was transferred and how this knowledge was transformed in this process. Furthermore, the Kenyan case has shown how a transfer activity might contribute to creativity, learning and socio-technical innovation. Conversely, the investigation of the transfer process has highlighted the importance of contextual factors for how an energy system works and the importance of seeing the energy models as dynamic and changing. The process has also given insights in the broad range of tasks and challenges that might need to be addressed by the involved actors in planning, implementation and follow-up of a decentralized infrastructure.

Each of the four empirical chapters contributed to both levels of research. They contributed to the first level by analyzing an existing example of socio-technical innovation on village-level solar power provision in India (Chapter 5) and by analyzing the Kenyan context and the process of designing, implementing and further developing a village-level model in Kenya (Chapters 6 to 8). Considered jointly, these empirical studies contributed to the second level of research by demonstrating and analyzing the main phases of a planned, social science led activity for transfer of socio-technical innovations between different geographical contexts, and how the research findings were used as inputs in the process.

The conclusions and recommendations fulfill the aim of providing knowledge on how something could be done differently in our societies, and also with some suggestions on how something *should* be done, consistent with Kalleberg (2009) description of a constructive research approach. As mentioned in the introduction, constructive research develops insights about alternatives to existing structures, distributions and practices, and their feasibility.

After answering the two research questions in the following two sections, the third section of this chapter takes a closer look at how the practical, pioneering efforts called socio-technical experimentation may be organized in order to facilitate fruitful learning processes for socio-technical change. Overall, this dissertation has shown that facilitation of creative, inclusive and committed learning processes is important both for the development of better and more inclusive energy models, for attempts of up-scaling, and for spatial transfer of innovations. The whole of this chapter therefore contributes, in different ways, to the knowledge on *how* such learning and socio-technical innovation might be stimulated.

9.1. The social organization of village-level electricity provision

The analysis of the Indian and Kenyan cases in Chapters 5 to 8 showed important aspects of the social organization of village-level solar power systems. The first research question asks which lessons can be drawn from these case studies: *How can village-level solar power supply be designed and implemented in ways that make them well-functioning and viable in the long run, useful for the community members and widely implemented and used?*

Based on a socio-technical systems approach, a framework of analysis was developed and applied, focusing on six interacting dimensions of each local case, including the relations to factors at higher geographical levels. The case studies in Indian and Kenyan villages thereby, in addition to providing conclusions to the research question, helped to explore how village-level electricity systems can be understood through a socio-technical systems perspective. The conclusions presented below relate both to the level of the framework of analysis (and thereby to previous research findings within the field of energy studies) and to the more abstract theoretical approach used.

Three main conclusions related to the first research question are presented below, pointing to aspects that have received little attention (or been absent) within the empirical literature of energy studies mentioned in Chapter 3. Several of the findings of this research are likely to be relevant for village-level electricity provision based on other technologies than solar PV, because they concern the social aspects of the systems and implementation of technologies in new socio-cultural contexts in general. The conclusions are likely to be relevant for research and practice in different societal contexts, but must nevertheless be used in a context sensitive manner – a point that is illustrated throughout this dissertation.

9.1.1. Context sensitivity and socio-technical flexibility enhances the functioning and usefulness of village-level power provision

According to this research, the search for knowledge on how village-level electricity systems can be socially organized should build on a realization that such local, socio-technical systems provide an opportunity to design power supply that is well adapted to people's needs and local conditions (Bellanca et al. 2013). Moreover, the achievement of viable, useful and well-functioning systems also *requires* serious attention to such needs and contextual conditions. The Indian and Kenyan cases demonstrate that the suitability of the socio-technical designs in their local socio-cultural context is likely to influence a range of qualities of the energy models, such as the relevance of the kinds of electricity services for the people, affordability, spatial outreach, the functioning of operation and maintenance, and economic sustainability. For instance, the use of portable lights in the Kenyan case made it possible for people to use the light for many different purposes, inside and outside the houses, for business and private use and by different members of the extended families. The case studies also show that the planning, implementation and long-term operation of a village-level electricity system is a process where innovative socio-technical designs meet and interact with contextual factors, through the different actors involved, both during the design phase before implementation and through the following phase of practical experiencing and learning through practice. This highlights the importance of seeing technological change as a gradual process of mutual adaptation between technologies and specific spatial and socio-cultural contexts at the local level, including users' practices and challenges, in addition to being a part of socio-technical systems and institutional frameworks (Ornetzeder and Rohracher 2005, Coenen et al. 2012, Sørensen 2013).

The dissertation has also shown that the details of the socio-technical designs (or electricity models), including the organization of their daily operations, matter for how local electricity systems work in practice and for whom, and thereby their long-term viability. Systems that look similar may function in different ways and give different opportunities for the users because of differences in the details of the design or operational routines, including women's roles. This has become especially clear through observing how small and gradual changes in the Ikisaya project in Kenya played a large role for how the system worked, how it suited people's practices and needs, and for how it can be replicated or built upon. The research and practice for development of practical, economic and equitable models for the local level is therefore important. Supportive framework conditions like the Indian, or new policies for promotion of renewable energy are not enough in themselves, as mentioned by Bellanca et al. (2013). The involved actors, including outside experts and advisors, therefore have to care seriously about the social, economic, institutional and operational details and how they are experienced by different people involved. Lack of such care has often been a shortcoming in implementation of technologies, including off-grid renewable energy projects.

Due to the importance of the details and contextual conditions, there is not one specific answer to how the involved actors can design, implement, follow-up and expand a village-level solar system or any other village-level electricity system. Careful development of socio-technical designs through collective learning processes for each local system is necessary, especially when developing new types of models or starting activities in a new geographical area. However, in efforts for replication, planning processes can be simpler. They can build on pilot projects where the initial design has been based on careful considerations of contextual conditions and people's needs and constraints. This was illustrated by the activities for replication in Kenya, which were significantly easier to implement in each village. Standardization might not be problematic as long as the model has been designed based on relevant contextual conditions and local realities, including the economic situation and practical needs of potential users of both genders.

As reflected in the framework of analysis applied – and convincingly shown by the Sunderban and Ikisaya cases – the socio-technical designs of an electricity model the way it is intended to work (here studied as dimension C of the framework) is not the same as how it works in practice (dimension D of the framework). This relates to the open-ended, unpredictable and uncertain nature of social and technological change (Russell and Williams 2002). The confrontation between the plans and real life conditions, including the economic and practical constraints of the users, leads to unexpected and unintended results (*always*, according to the literature) for all involved actors. The collective learning continues after implementation, and requires good follow-up of local actors, monitoring and analysis of results, and joint planning of changes between project implementers and local actors. The socio-technical design process thereby continues.

In the case of Ikisaya, for instance, the most intensive learning process took place after the start of the power provision, in cooperation between the project team and the staff and board members. These actors worked to find out how it could actually be possible to meet the users' needs, give broad access, and fulfill objectives for economic performance (level of revenue, banking routines, saving, maintenance and expansion) which they had expected that the initial design would have solved. This is the typical learning through trying, failing, learning and trying again in practical projects for socio-technical change, as the theoretical literature explains (Berkhout et al. 2010). Such unexpected problems and learning processes were important in the Sunderban case also, as explained in Chapter 5, but in the case of Ikisaya it could be observed at a much closer distance and in the most detailed way. The Ikisaya case also showed that a socio-technical design that has some built-in flexibility (like the modular system for lantern charging) allows for simple changes that can help improving its suitability in the socio-cultural context and dealing with uncertainty and unexpected problems, as mentioned in Ulsrud et al. (2015). It facilitates creativity and innovation by local actors based on practical experience and feedback from the end users.

This research suggests that projects and programs in the field of village-level electricity provision could focus on gradual learning to a larger extent, and emphasize various kinds of innovation (e.g. technical, social and institutional). Such a learning approach could facilitate adjustments and improvements through learning by doing for project implementers and actors at the local level, and thereby ensure the long-term viability of the systems. Sufficient resources (time, funds and committed persons) should therefore be allocated to the phase after implementation. Many kinds of models can function well if they are implemented and followed up well.

However, trying and learning is not sufficient in itself. According to the Indian and Kenyan cases, an important ingredient in such learning processes is that some of those who participate have advanced knowledge and expertise of this field of practice, accumulated from emerging niche developments, and cooperate with local actors in committed ways. Both cases as well as the previous literature on village (or community) energy, including European examples have demonstrated that advice and support for the local actors is important (Walker and Devine-Wright 2008, Avelino et al. 2014). Moreover, though the village power provision can and should be organized in context sensitive ways, it is also possible to identify more specific factors that are likely to influence how it works, for instance the importance of avoiding large battery banks that undermine the chances to achieve economic sustainability. Such specific factors have been suggested in the conclusions of the Indian and Kenyan case studies (in Chapter 5 and Chapter 8).

The value of collective learning, follow-up, and flexibility is related to the concept of users' innovation in socio-technical design processes and learning through practical engagement with the technology (Ornetzeder and Rohracher 2005). According to this research both a flexible design and flexible project implementers facilitate user innovations in socio-technical experiments, not only before practical implementation, but also after. Within the room for maneuvering created by existing technical equipment, its costs and other constraints, it is possible to adjust the socio-technical design according to the ways in which the users appropriate and domesticate the technology (Sørensen 2013). Appropriation and domestication are both influenced by and influence people's practices, and these are part of broader socio-cultural contexts of livelihood struggles, climatic conditions, agricultural seasons and social norms. Users' innovation can be facilitated by long-term cooperation and co-generation of knowledge between various kinds of actors, including the important operators at the local level and the "end users" of the electricity services. Monitoring local electricity systems, for instance through the use of qualitative social science methods can help to pay close attention to evolving practices and ideas.

When analyzing energy projects as socio-technical experiments it might sound un-ethical, because of the notion of "experiment". However, a learning approach to electricity provision as described above is most likely to *improve* the usefulness of the electricity systems for the users and *reduce* the number of non-functioning technology installations. Importantly, projects in real life settings should absolutely be viewed as "the real thing" meaning something that is going to work and last, be widely implemented, and not as "experiments". The projects must not be left on their own after implementation as just a pilot or experiment, useful for learning, but not seen as having much value in themselves.

Although the social aspects are crucial for the functioning of an electricity system, seemingly small technical shortcomings may also have large importance, such as the number of days that lantern batteries can hold power or the number of years that power plant batteries can last. Both in the Indian and the Kenyan cases such technical characteristics affected the entirety of the local socio-technical systems, not least the economic performance. Such seemingly small issues are important for future, rural power provision, because off-grid systems, including village power plants, solar home systems and portable lanterns or other portable devices might be among the most realistic and relevant options for providing basic electricity services for a large number of people for many years to come.

9.1.2. There is still much to be done on equitable distribution of electricity access

As pointed out by Stirling (2009), equitable social distribution of economic resources, technology and benefits from innovation should be an important guiding principle for future sustainability. Some off-grid solutions (solar home systems, diesel generators, and small solar lighting systems) as well as conventional grid extension tend to reach the wealthiest groups of each local community because of the upfront costs and monthly fees that are higher than what the majority can pay. This research shows that village-level models can be designed in ways that provide access to basic electricity services to a larger portion of the population in a poor, remote community than other models normally do, supporting Palit (2013) and Wong (2012). However, even with such models, significant portions of the community members may still not be served. (The notion of basic electricity access relates to the first level of UN's three step scale of energy access, as explained in Chapter 3.)

Ambitious guiding principles that point towards an equitable and environmentally sustainable world are often applied in idealistic efforts for social transformation, including the Sunderban and Ikisaya projects, thus representing ideas for radically different societies than the current. It may not be surprising that some of these objectives are difficult for energy practitioners, NGOs, governments and private businesses to achieve, as shown in the literature and illustrated by these cases. Some objectives are easier achievable than other ones. These include well-functioning operation and maintenance, gender and context sensitive approaches, as well as modest investment levels. The three most difficult objectives to fulfill are broad access (or access for all), economic sustainability and possibility to replicate the models. Such difficulties were illustrated both by the Indian and Kenyan projects, and by the fact that few or no examples exist (according to the literature on village-level power provision in the South) where these three objectives have been fulfilled together.

Economic ideas as well as requirements for economic performance in an electricity project or business have an impact on who gets access or not. In line with publications on village-level electricity provision, economic sustainability was found to be an important quality also in this research (Shrank 2008). If economic sustainability is achieved, it leads to independence of continued funding support, and thereby reduces uncertainty and vulnerability for the local system. However, many people may not be able to pay the prices for electricity services that are necessary for economic sustainability, and some may not be able to pay anything at all, because they cannot even afford to purchase enough food or pay school fees for their children.

The cases demonstrate that even in initiatives where the principle of equitable distribution of access to electricity is kept high on the list of priorities, it can be difficult to achieve both affordability and economic sustainability. The figure below illustrates this dilemma, and the cases have shown examples of how project implementers as well as users of electricity have attempted to overcome it. The project implementers in both projects tried to balance affordability and economic sustainability in their considerations for the socio-technical designs and in their responses to the users' requests and practices. The users tried to make the services affordable for themselves by challenging the limitations of the systems. In the Sunderban, this was a part of the reason for illegal connections as well as light points or sockets beyond the agreed number. In Ikisaya, this was an important reason for the users' tendency to keep the lanterns for a few extra days while refusing to pay extra for this.

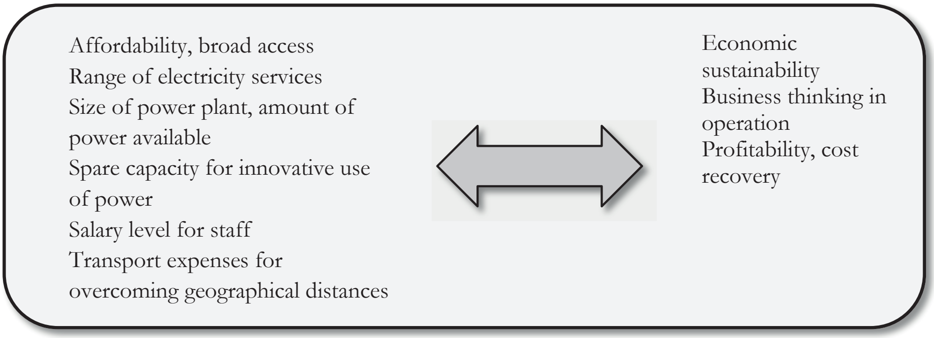

Figure 20. Dilemmas and needs for balancing between economic sustainability and other desired qualities.

There is not only a dilemma between the two goals of affordability and economic sustainability; there is also a mutual dependence. As reflected in the project implementers' considerations for the socio-technical design for Ikisaya, and probably also for the Sunderban systems, the economic sustainability of a given project depends on the relevance and affordability of the services for the potential users and thereby the number of users who choose to use the services. The prices must be set at a level that makes the services affordable for large groups in order to achieve good economic performance.[98] However, both cases also illustrate that in attempts to balance the two, both objectives might be compromised to some extent.

These cases and the existing literature clearly show that providing access to electricity services for *all* in a poor, remote community might not be possible without providing electricity services at subsidized prices or for free, thereby going away from the objective of economic sustainability (or commercial profitability) in operation and maintenance. (Subsidized systems can be observed for solar micro-grids in Chattisgarh state in India, as mentioned in Chapter 5.) This means that the depth of the challenge of providing electricity to all may not yet be sufficiently well understood. This challenge requires strong attention in future research, policy and practice on how electricity provision can be socially organized, including the ability of the people who live in areas where electricity lines are already present to actually get connected. The entry costs to conventional electricity grids are far too high for most people in rural areas in Kenya and many other countries in the South (Abdullah and Markandya 2012).

The entry costs were low in the electricity systems studied here. However, a low entry cost does not help if the price for use of electricity is still too high for many community

[98] An exception can be if there are some customers that can use large portions of the electricity being "anchor customers" that secure the survival of the system.

members. The Ikisaya case suggests that access is enhanced if there is no obligation to use the electricity services neither regularly nor sporadically after registering as a user. The amount to pay per month can thereby be adjusted by people according to their economic situation, which typically varies much with the agricultural seasons and periods of extreme weather conditions. However, this is again a solution that reduces power plant revenue.

Down-sizing of the models is a strategy for improving economic performance, as shown both on the way from the Sunderban model to the Ikisaya model, and further to the "agent model" tested by the government contact in Kenya, keeping only the most necessary services (lantern renting and phone charging) and minimizing expenses for operation and maintenance. For instance, economic performance is enhanced by reducing work-demanding services like the provision of typing services. If commercially profitable models are the goal, further down-sizing might be necessary, since these not only have to reach economic sustainability, but also profitability and recovery of investment costs.

These insights mean that economic objectives and requirements applied in practical efforts for socio-technical change, including the attention to equity and societal improvement, influence the types of ideas and socio-technical designs that are developed and tried out in practice (Leach et al. 2012). This research also indicates that innovative, but careful real life projects are useful arenas for learning about different kinds of socially motivated economic thinking as a necessary part of exploring pathways towards sustainability. Such practical projects and grassroots innovation, possibly in combination with action research provide a chance to explore what a "green economy" with emphasis on social equity might look like, reminiscent of suggestions by Seyfang and Smith (2007).

9.1.3. Diversity and gradual learning is important for replication and up-scaling

As mentioned earlier, replication here is not taken to mean direct copying (which rarely happens), but that project implementers or others build on a model that they have tested or observed, at the same time as they bring in other lessons learned and new ideas for improvement. Replication, niche formation, and up-scaling has not been directly studied in this research, but the Indian cases as well as the action research in Kenya have provided insights in factors that are likely to play a role. The cases have shown examples of early stages of replication activities as well as diffusion of lessons from the experiments, as explained in Chapters 5 and 8.

In the Sunderban case study, WBREDA's experiences from implementation of mini-grids in 17 villages gave insights into what kind of coordination, institutional framework, implementation strategies and follow-up could be required in up-scaling a decentralized infrastructure. Moreover, the Sunderban activity was a source of learning for a large number of actors involved, on different societal levels, and in many places, including Ikisaya. Although the mini-grid projects led to some unfulfilled expectations, they were probably a significant part of the broader learning processes and strengthening of off-grid solar PV activities both within and outside India.

The spread of agents around Ikisaya and the follow-up activity in other parts of Kenya (including Turkana) described in Chapter 8 also represented attempts of replication, building on the elements of the Ikisaya model that could be possible to repeat in larger numbers. Discussions in the project team on the replicability of the Ikisaya model during different phases before and after implementation also shed light on this theme. As shown in the earlier chapters, the project can be said to have stimulated niche internal processes through comprehensive learning processes for the people involved, and various ways of spreading lessons from the project, as well as strengthening of networks. Visions and expectations for future use of solar PV among involved actors and observers were also influenced. For instance, team members gave increased attention to simple charging stations for lanterns and phones and their replicability.

According to the observations on replication of village-level electricity models in the two cases, it can be concluded here that replication depends on several kinds of factors. Firstly, it depends on characteristics of the local electricity models, which affect the chances of different actors to replicate them. These include the investment costs, the organizational and operational aspects, the economic design and performance, and the time and resources required for the implementation process and follow-up. Secondly, the kinds of actors involved influence the possibility for replication of different pilot and demonstration projects. Different kinds of actors (NGOs, private sector, governments, etc.) will have different opportunities and ways to plan, implement, follow up and expand energy systems, discussed in relation to the case studies. They will thereby differ in the kinds of models that are of interest for them, based on ideologies as well as their opportunities and constraints. Thirdly, the geographical areas for the activity also influence replicability due to different settlement patterns and other features. Fourthly, replication of an energy model depends on the actors' availability of financing the activity as well as other framework conditions, such as availability of suitable technological equipment in a specific country. Governments, financing institutions, donor agencies and other niche, regime or mixed actors can have a large impact on the possibilities of other actors to contribute to replication and strengthening of niches, including private sector. For instance, the support from a funding organisation for replication of an "agent model" in some hundred villages in Kenya constituted a valuable opportunity in this regard.

Although the ways of organizing the systems at the local level are crucial for how the technology works in practice in local communities, conducive framework conditions are important for the possibility to implement decentralized electricity provision in a large number of communities. The "drivers and barriers" include policies and industry characteristics nationally and internationally. Innovation in governmental frameworks, regulation and policies are likely to be important in order to facilitate wide-spread use of village-level models. These must build on an understanding of the requirements of the local systems and the opportunities and constraints that the different change agents meet. The policies should also aim to address weaknesses of the wider solar PV and renewable energy sectors nationally and internationally, which the local projects depend on.

The many kinds of factors that influence replication indicate that understanding of what is replicable and for whom and under which conditions has to be achieved through careful and gradual learning processes on replication (and up-scaling) itself, involving institutions at different societal levels and relating to specific national and local contexts. Such learning can be enhanced by encouraging diversity in replication initiatives, including diversity in actors (and thereby visions and motivations), diversity in types of models to be replicated, diversity in support mechanisms and a diversity of kinds of places and socio-cultural contexts that various models are adapted to. Such diversity (i.e. variation) is likely to be a useful principle for replication and up-scaling of village-level power, not only for pilot- and demonstration projects. Both the experimentation (i.e. variation) and the selection processes should be broad.

This is also in line with theoretical recommendations of probe and learn strategies in governance (Hoogma et al. 2002, Smith and Raven 2012), which recognizes that policies for strengthening of niches should be dynamic, reflexive and open-minded, by observing and modulating the direction of on-going processes. A challenge is that dynamic policies must be balanced with predictability over time for the actors who contribute. This way of thinking, based on the literature on socio-technical change and transitions could to a larger extent be adopted in energy research and practice. Funding models, such as programs under “Sustainable Energy for All”[99], should be developed in ways that suit the village communities and the different kinds of actors that might work with them, as well as for governments that can use such funding in order to develop suitable support mechanisms.

A challenge that should not be neglected is that there are dilemmas between replication or up-scaling on the one hand and securing important qualities of pilot and demonstration projects on the other hand. These qualities include the emphasis on learning processes and innovation, gradual expansion, context sensitivity and equity. These dilemmas will vary according to the kinds of projects and other actors involved, but are likely to play a role in most cases. In the Sunderban case, the project implementers found it necessary to outsource the follow-up of an increasing number of projects. A potential replication of the Ikisaya Energy Centre model, not only the “agent model”, would have required institutionalized follow-up, and even the replication of “agents” requires an arrangement for coordination and follow-up.

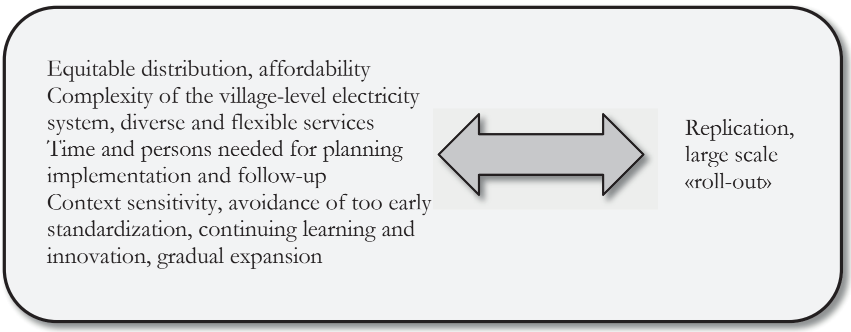

Figure 21. Dilemmas involved in replication.

[99] http://www.se4all.org/about-us/

An alternative approach to replication of decentralized infrastructure can be imagined based on this research. It might be important to acknowledge a need to facilitate complexity, follow-up and context sensitivity. Committed advisors can follow up a number of projects, and these advisors could be people who have gained experience of implementing or managing electricity systems in villages. Such an approach means more time and human resources invested, stronger focus on the human dimensions of the energy systems, and acknowledgement of the complexity and dynamic nature of socio-technical systems.

Some organizations, such as NGOs, are probably working in such ways in various activities at the local level. However, this is a radically different approach than what is common in the off-grid energy field in the South, according to experienced energy practitioners. This would mean an increase in "soft costs" (or administration costs). It would also require building up institutional infrastructure and human resources within organizations. Such an approach might be necessary for providing electricity to all. It could also be combined with other kinds of initiatives that are urgently needed in the villages, in fields like water, health, income generation and adaptation to climate change.

There is certainly need for continued social science research on how electricity access for all can be possible. The purpose should not only be academic, but also social and practical, as suggested by Kalleberg (1993). Further research on village-level models can focus on mechanisms of replication, up-scaling and institutionalization – including how village-level electricity models can be followed up in a large number of places in various geographical areas. Research on processes of replication and focus on up-scaling should not lose the attention to the substance of the socio-technical models to be replicated and how they function for the involved actors in specific socio-cultural contexts, including who can be able to benefit.

9.1.4. Reflections on the future role of village-level power provision

A diversity of electricity models are likely to be necessary in order to provide access for all, and can complement each other. The dissertation has studied village-level systems because they could be an interesting option. However, individual off-grid solutions and centralized grid extension are also likely to be important, not only in different geographical areas, but even in the same locations. Different models provide different kinds of services suitable for the needs and economic situation of different users.

The potential role of village-level power provision for the future is likely to depend on the usefulness, feasibility and scalability of this type of model for different user groups compared with other types, and the political and economic power and influence of those actors that promote the different options. A systematic comparison of the three main options known today, centralized grid extension, village-level models (mini- and micro-grids, energy centres, charging stations) and individual user models would require comprehensive research on all options, while only one of them has been studied here. However, observations on the two other options, especially in Kenya, provide an opportunity for a brief comparison. It is important to keep in mind that the feasibility and desirability of a specific type of model is highly variable depending on how it functions in each case – a well-functioning electricity grid is very different from one that hardly works, for instance. Moreover, the affordability of grid electricity varies across countries. Similarly for the two aforementioned off-grid models – their actual functioning influences the way the system is experienced and viewed, both by users and observers. It is nevertheless possible to discuss advantages and disadvantages of the three kinds of options (i.e. their usefulness and for whom).

Advantages of grid electricity, where it becomes available and if it gives reliable power supply include the availability of larger amounts of electricity than a village-level system can normally provide with today's technical and economic options. Disadvantages are that they mainly serve those living along the main roads (the way the grids are normally installed). Moreover, very few people in remote, poor villages can normally afford to connect. Branching out lines from the main routes is very expensive, and significant portions of the population in dispersed settlements might therefore not be reached.

Decentralized, off-grid power provision also has limitations, and in some cases they may be needed only temporarily. According to the project implementers in the Sunderban, village-level systems might be useful for people in an early phase of providing electricity services. When people gradually start demanding more electricity, dissatisfaction with the basic services may appear. Decentralized solutions (like the mini-grids and solar home systems in the Sunderban) thereby prepare communities for grid connection. This makes grid extension more economical, and can be viewed as "pre-electrification".

However, decentralized models are likely to be the only option for many people in many places for a long time to come (World Bank and IEA 2013). It is therefore important to continue developing better decentralized models, as well as institutional frameworks that facilitate them. Even in places where the grid arrives, it can be important to continue providing decentralized solutions, because many groups might not be able to connect to the grid. Simultaneously, there is need to consider how the grid electricity can become accessible through becoming more affordable and branching out the electricity lines to more homesteads. Ikisaya as well as Sunderban provide interesting examples for future investigation of what happens when already installed off-grid solutions meet centralized grid extension.

Advantages of village-level systems made them interesting for this research, including their possibilities to solve some of the previous challenges for the use of solar home systems, such as investment for users, battery replacement and other maintenance. Village-level systems also have potential to provide additional kinds of electricity services than the smaller systems. Over time, those who promote household systems, including solar lanterns, have achieved technical improvements, price reductions and innovative business models, although there are also many products of poor quality. Fee for service solutions (such as monthly payment for keeping a solar home system and use different electricity services from it) and payment in installments as well as smaller systems, including solar lanterns, have also helped to solve challenges. Battery replacements and other maintenance has become cheaper and easier. Some therefore question the need for village-level solutions in off-grid areas. The diffusion of individual systems is quicker than the diffusion of village-level systems. However, the portion of users in each local community is still likely to be small in most places, while a village power system might be able to connect more people in one place, and still has the potential to provide additional electricity services for the communities.

There is probably a potential for improvement in both kinds of off-grid models. Organizational and economic challenges of village-level systems might decrease, either through simpler models, better follow-up and support (and better socio-technical designs) or models operated professionally by utilities, as the larger isolated grids (a kind of large mini-grids) in Kenya.

Among the advantages of village-level, locally operated infrastructures, when they work well, are that they can be valuable institutions for communities, likely to create new ideas, knowledge, and capacities. In Sunderban for instance, the solar PV technology became familiar among community members, and those who could afford it combined the community power supply with private installation of solar PV. In Ikisaya, based on good leadership shown by a young woman it became a common and accepted practice to train young women in technical and economic skills when new assistants or agents were needed, among other things. Such kinds of positive extended effects are mentioned in the literature on the projects in the UK as well, including the creation of trust and social capital (Hielscher et al. 2011).

If the projects get problems and do not get assistance, they might break down and create stress and disappointment in communities. However, problems can also lead to constructive struggles for solving them. One potential way of increasing electricity access is to upgrade and restart infrastructure that has stopped working and where local people are interested in doing so, but are lacking financial means and are in need of advice. The actual use of the different models in the future will not only depend on the feasibility and desirability of the different models, but also on the interests of those who have the largest influence on the choices and directions taken for the future. If local people could choose, some of them might say that they have found village-level solutions more suitable for their needs, again depending on the details of the models and how they function in practice. However the strongest economic and political interests within the use of solar PV technology today seems to be within grid-connected, large installations and on the mass market for household systems, including solar PV lanterns. Thus, the choices of models and how they will be combined are political, economic, technical and practical.

9.2. International transfer of socio-technical innovations

At the second level of research, and in order to answer the second research question, the dissertation has described and discussed a process of transfer of innovations between places and countries in two different world regions. This process was generated by a planned strategy to investigate a relevant example, "lift" it out of its socio-cultural setting, and bring it into a different local and national context – one with similar challenges in infrastructure provision. A process of translation and adaptation was anticipated, and the involved actors attempted to facilitate this. The second research question focuses on what can be learned from this specific case that can have broader relevance for the transfer of innovations between different socio-cultural contexts: *How can social and technological innovations on local* *infrastructure systems be transferred between geographical contexts?* An interesting aspect of this question relates to how it can be possible to combine spatial transfer with local embeddedness of innovations.

This second research question has been explored through the three sub-questions presented in Chapter 1. These concerned the main characteristics of the process of transferring social and technical innovations between India and Kenya, the ways in which the process led to its various outcomes and extended effects, as well as how the differences between the Indian and Kenyan contexts at the local and national level influenced the process and its outcomes. These questions have been answered through the Chapters 5 to 8.

Recalling the previous chapters on different phases of the transfer process, the process was composed of the following interacting and overlapping main activities: 1) Preparations with Kenyan energy experts, 2) Research and study tour in India, analysis, 3) Selection of location in Kenya and study of the national context in Kenya, 4) Study of the local context in Kenya and cooperation with a Kenyan village, 5) Development of system design, 6) Procurement, training, and start-up of electricity provision, and 7) Follow-up, support and advice at the local level, and research on how the model fared (monitoring and analysis). The figure in Chapter 6 illustrates how the activities overlapped over time.

The dissertation has shown that the five-year process can be seen as three kinds of phenomena at once, as indicated earlier. Firstly, it can be seen as a process in which ideas, experience and technical equipment were transferred between places and countries, and between the involved people. The activities listed above can be seen as different phases of a "de-contextualization" of the Indian experience, and "re-contextualization" of elements of the Indian experience in Kenyan contexts (Raven et al. 2008). The case can thereby contribute to knowledge on inter-local learning (learning between projects or socio-technical experiments) and international knowledge sharing in general. Secondly, the process can be seen as a creative learning process that has similarities with bounded socio-technical experiments and grassroots innovation. It can thereby contribute to the knowledge on how learning and innovation takes place in such experimentation. Thirdly, the process can be seen as a research process, where action research was used as part of a broader, constructive and trans-disciplinary research design. It can thereby provide knowledge on how social science contributions, trans-disciplinary cooperation and action research can play a role in socio-technical change and transfer processes.

Viewing the process through these different lenses provides different perspectives on the same case and a better understanding than if the process had been viewed as a case of one of these phenomena. The following sections answer the second research question and discuss what this combination of perspectives means for theory (and practice) on spatial transfer of innovations and other deliberate socio-technical change, and for the role of social science in such change efforts.

9.2.1. Spatial transfer of innovations might best be seen as outward bound activity

Approaches to spatial transfer of innovations, usually called technology transfer, have to a large extent been oriented towards countries in the South as recipients of technology, as explained in Chapter 2. Most of the literature on technology transfer indicates a situation where there is movement in one direction, from the first to the second context, using concepts like "originator" and "recipient". A different starting point for thinking about spatial transfer of innovations, "inter-local learning", comes from research on socio-technical experimentation in the North, and describes a situation where project actors who want to develop and try out new socio-technical designs draw on lessons learned in other activities. The starting point for inter-local learning is that the actors who are planning a practical activity search outwards to other places and countries for relevant examples, knowledge and experience to build on.

This dissertation suggests that transfer of innovations might fruitfully be seen as an outward bound, inspired activity that starts where the new knowledge is going to be used, in line with the literature on inter-local learning. The activity can thereby, already from the outset, be embedded in a context of relevant, interested actors and emerging technology sectors (socio-technical niches and ongoing system innovation) in the "recipient country".

The strategy analyzed here was based on ongoing work in Kenya, needs for new ways of using the solar PV technology, interested persons and existing skills and experience in the field of off-grid renewable energy and solar PV in the country. The shortcomings and challenges of the established energy regime (conventional grid extension and centralized electricity generation) had motivated activities on decentralized solutions based on renewable energy technologies as explained in Chapter 6. The Solar Transitions project had the potential to add useful experience, according to Kenyan renewable energy experts. The idea of learning from India and trying out a new model in Kenya (although the idea initially came from an outsider) was supported by several "niche actors" placed at a middle level of the energy sector (researchers, consultants and government officials), some of which became members of the project team. When the team contacted the local community and government administration in the village Ikisaya they also strongly supported the idea.

In these ways, the strategy was "rooted" in Kenya before other steps of the knowledge transfer from another country were taken. The social science study on the national framework conditions contributed to the same, in combination with a number of meetings with relevant actors as described in Chapter 6. Significant parts of the project planning in Kenya took place before the examples in India were studied. These features of the activity appeared to contribute to the integration of the project in parts of the Kenyan renewable energy field. This starting point enabled the project to contribute to the accumulation of knowledge and experience within the work on solar PV technology in Kenya, and facilitated gradual impacts on the same field over the five years included in this analysis, as explained in Chapter 8.

One of the reasons why the initial phase of establishing an activity is likely to affect the whole process and its outcomes, is that the gathering of collaborating actors takes place in this phase. The whole transfer process is likely to be strongly affected by the actors who participate in the activity, their previous knowledge and interest in the field, and their commitment. In a strategy for systematic transfer of innovations, the actors' ways of studying examples, and their position to utilize the new ideas in ways that fill in the missing pieces can have a strong impact on how the process will unfold and how it may influence system innovation in a country, according to this research.

Some key individuals might be decisive for the outcomes of a transfer process. In the case analyzed here, several individuals played important roles for the outcomes and their features. Everyone in the team influenced the work in various ways. The Kenyan team members had good background knowledge and were eager to increase their knowledge on solar energy solutions. They were therefore able to bring the knowledge from India back to Kenya and use it there, and also share it with others and suggest new initiatives. In addition, several of those extended effects that appeared in Kenya as a result of the transfer activity was due to the participation of one specific individual, the government official who had entered the team on his own initiative.

Some of the first effects of the transfer activity appeared long before the team's own pilot or demonstration project started operating in Kenya, due to the invitation of this government official for the visit in India. He utilized the information immediately in two different kinds of projects, including the installation of solar power generation as an addition to diesel generators in some of the isolated power stations in Kenya. These activities were extended effects of the transfer activity itself, not of the specific project carried out in Ikisaya village by the project team.

This person was able to achieve these results for three main reasons. Firstly, he was a skilled engineer, centrally placed in the work on isolated diesel power grids in Kenya. Secondly, he had good contacts in the Ministry of Energy, although they had so far not supported his ideas of testing solar PV in combination with the diesel generators. Thirdly, he had on-going cooperation with a professional contractor company on electricity generation, including renewable energy. What was transferred, or rather created, in this particular example, was strong inspiration and a belief in what was possible to do, as well as important information that could fill in some missing pieces in figuring out how to do things, and not least to convince actors in the conventional electricity sector (or regime). This individual actor thereby found the personal "empowerment" he needed in order to subsequently "empower" the solar PV technology within the established electricity regime in Kenya. As mentioned in Chapter 2, Smith and Raven (2012) define empowering of a niche technology as niche influenced changes in regime selection environments. In this case, the Ministry was an important part of the selection environment for solar PV technology in Kenya, and it became more conducive in this process. The inspired individual made the Ministry (through a central person) change from rejecting his proposals on trying solar PV in one of the isolated power grids, to ask him to install larger capacity solar PV installations than he had proposed, and in an increasing number of power plants. This contributed to normalizing solar PV as part of the government's work.

In general, the case shows that there might be a strong value in being able to go to another country to get first hand access to relevant experience and consider whether the solutions can be relevant for your own country and how they can be adapted to national framework conditions and local contexts. The framing of spatial transfer of innovations as an outward bound activity represents a very different approach than if it is seen as an activity where experts from abroad would come and initiate technology projects and share their knowledge as a more top-down activity, which has generally failed in the past (Metz et al. 2000). The transfer activity studied here was bottom up as seen from the perspective of "middle-level" actors who work with and for people at the grassroots level and who work to promote electricity provision alternative to the mainstream.

This research also shows that one should not assume that learning from other places and countries is an option that is available for all. There are barriers for learning from relevant examples elsewhere, and there are considerable global differences between actors' opportunities to study socio-technical innovations in other places and countries. Practical and economic hindrances can play a role. Freedom to travel is a privilege that is taken for granted among many in the North, while it is not an available option for most people in the South, not even for professionals with good jobs and decent salaries. International travel is prohibitively expensive relatively to the general level of prices and incomes in many countries in the South, in contrast to the relative costs for travel in many countries in the North.

Lack of contacts and networks in other countries can also be a barrier for international knowledge sharing. The transfer activity in this case addressed such barriers and worked as a catalyst by creating a meeting place for people from different countries interested in the same topics. The opportunity for learning from India in this case was created by an academic-practical project that provided time and recourses for participants, including the involvement of a resourceful partner organization in India. This partner provided other contacts in India and facilitated comprehensive interaction over long time.

9.2.2. Technology transfer and socio-technical innovation are mutually supporting

Some of the recent literature on technology transfer in and to the South points to the need for viewing spatial transfer of innovations as complex, social learning processes based on knowledge presented in the "recipient" countries. Suggestions by Byrne et al. (2011) and Romijn and Caniëls (2011) have been found to be particularly relevant and are strongly supported by this dissertation. They argue that socio-technical experimentation over time is a necessary part of spatial transfer of innovations in order to create an arena for cooperation, learning by trying and learning by developing social and technological changes suitable for local needs and contexts.

Going beyond existing research, this dissertation has provided a rich, empirical example of how transfer of innovations may take place in ways that stimulate social learning and innovation in a new spatial context. The dissertation has explored how a spatial transfer strategy might be organized in order to facilitate a creative learning process, combining the knowledge of actors with different kinds of knowledge, including grassroots representatives' local knowledge and experience.

The analysis shows that a central task for actors involved in spatial transfer of innovations is to find out how the knowledge obtained on relevant examples can be used in ways that suit different contexts. In the process of adapting socio-technical innovations to a new context, new innovation has to take place. It is never clear in advance what the outcomes will be, they must be worked out gradually. The analysis also shows that it matters how the process is organized.

The description of the "Energy Centre" model development in Kenya, in Chapters 6 to 8, shows that the most important feature of the transfer process from India to Kenya was the joint learning and innovation process for the involved actors. There was a dynamic interaction between the characteristics of the applied strategy (including the composition of the team, the guiding visions, tasks to be solved, steps taken, and ways of interacting with a village community) on the one hand, and the constraints and opportunities created by a range of contextual factors (inside or outside the control of the involved actors) on the other hand. The process was complex and dynamic, and full of uncertainty and pondering on what could work. The initial plan for strategic steps was combined with a range of adaptations and changes underway, and the emergent outcomes had an impact on the further steps. The limitations of the room for maneuver led to ideas for how to stretch the limits, and the attempts to stretch the limits led to new learning on hindrances and opportunities. The combination of a systematically planned strategy and an adaptive way of carrying it out was necessary and fruitful, supporting a point made by Brown et al. (2003) on the importance of changing course underway in strategies for socio-technical change.

According to this case, transfer of innovations and socio-technical experimentation are not different phases in the same learning process, but rather different dimensions of the same process. In some phases there might be more emphasis on how and what to learn from other places, and in other phases there might be emphasis on the new activities inspired by the transfer strategy. It is not possible to say where the transfer process ends and the learning and innovation starts. Several phases of the transfer process, both during the planning phase as emphasized above, and when trying out the new ideas, can be seen as socio-technical experimentation in one spatial context.

The main, direct outcome of the transfer process analyzed here was the establishment of Ikisaya Energy Centre, with agents or sub-centres in neighbouring villages. Since this village-level solar power system implemented in Kenya became very different from the examples studied in India, it may be asked what was actually transferred, and how. It could seem like the development of a project in Kenya was the key part of the process, while the transfer of lessons from India was less important. The previous three chapters have shown how the insights from India were combined and mixed with other knowledge, experience, and ideas, leading to the creation of new knowledge and ideas underway. Certainly, the learning from India represented only part of the inputs that led to the Ikisaya model, but important experiences and knowledge were transferred between projects, people, places, and countries. Access to specific types of technical equipment and advice from India also had strong impacts on the model.

This means that the Sunderban mini-grid systems mostly had an impact in indirect ways through influencing the kinds of aspects considered for the Ikisaya activity. What was transferred from these examples was not specific socio-technical innovations or models, but rather the knowledge and experience of actors who had created them and struggled with them over time. Inspiration to try out new ideas was also part of the process. Learning from problems (or "failure") was certainly relevant (Brown et al. 2003), and quite important in this case, although positive results had also been achieved in the Sunderban projects. The modular equipment for charging of lanterns, developed in other projects in India, was very important for the socio-technical configuration of the Ikisaya model, but was still not a direct transfer of a socio-technical design, because the equipment from India got integrated in a different economic, operational and organizational design in Kenya. Such mechanisms are likely to appear also in other cases of strategic transfer of innovations.

The expertise, experience and knowledge of the Indian partner had significance for the process and its outcomes. A different partner could have influenced the team's considerations and choices differently, and could have provided less assistance for the team's problem solving. Long-term linkages with Indian experts were important, for instance in order to transfer specialized, new equipment from India and to receive advice on challenges met in the Kenyan project. The *kind* of partner and collaboration (a common research project) facilitated open sharing of knowledge, and a kind of "open source" access to equipment and experience for the project team, since the transfer process was not based on trade interests or other economic interests related to industry or production.

As suggested in the literature there is an ongoing aggregation of lessons learned in the emerging socio-technical niches. In addition to direct learning between the experiments (inter-local learning), such aggregation takes place through the various ways of diffusing information from the local experiments (Geels and Raven 2006, Raven et al. 2008). In this case, the stepwise learning process from the specific case in Sunderban interacted with more sporadic learning from a variety of cases through the team members' background knowledge, in addition to a range of other inputs. However, the learning process from Sunderbans to Ikisaya was significantly different from the learning from other projects and countries and consisted of a comprehensive, strategic flow of activities and events, as described in the previous chapters. The additional learning was mostly implicit and came from various projects where team members had been involved, as well as from the aggregated knowledge in the solar PV and renewable energy sectors in different countries and internationally. All these sources of knowledge formed part of the team members' perceptions of what may work in places like Ikisaya or not, and their capacity to imagine different kinds of solutions.

A question about transferability raised in literature on inter-local learning is under which conditions findings on socio-technical innovations can be transferable between spatial contexts (Coenen et al. 2012). This relates to how geography matters for the local socio-technical changes that have emerged in a place or country and the relevance of transferring such innovations to different spatial contexts with different local conditions.

This research indicates that different *kinds* of similarities and differences between the local conditions may play a role for the relevance of transferring innovations between the contexts, and that the most important is similarities in problems to be solved and need for social and technological change. The most important similarity between the Indian and the Kenyan context for the transfer process was the need for developing innovative solutions for electricity access in poor, remote areas. This common need had already led to experimentation in both countries on various off-grid, decentralized, renewable energy systems, using solar PV and other technologies, but in different ways. This had created an opportunity for learning between them, and made the South-South transfer highly relevant despite the many differences both in the local, socio-cultural contexts at the local level and the national framework conditions.

The differences between the Indian and Kenyan cases in socio-cultural contexts and national framework conditions influenced the outcomes, but did not make the transfer activity irrelevant. It was necessary to pay close attention to the details of the social context in Kenya where the ideas and knowledge was to be used. The differences between the Indian and Kenyan contexts stimulated learning and creativity because they necessitated different solutions. Interestingly, not even insights from other poor, remote places in the same country can be assumed to be directly transferrable. Kenyan team members frequently pointed out significant contextual differences between Ikisaya and other places in Kenya where they had been involved in other energy projects. Moreover, one of the most important solutions for dealing with the differences between the Sunderban villages and the Ikisaya type of village was found in other projects in India than the ones studied thoroughly.

Based on the abovementioned arguments, the question about the conditions for transferability may not be as important as the question of how the transfer process can contribute to creative learning processes and mutual embedding and adaptation between socio-technical innovations and new social contexts, including local socio-cultural structures. Even if the initial "conditions for transfer" seem to be good, for example in terms of many similarities between contexts and common problems to solve, it is not likely that innovations can be copied through a blue-print approach (Raven et al. 2008). This is richly illustrated in this dissertation, which shows that the question about how transfer of innovations can be organized, might be at least as important as the question about conditions for the transfer.

9.2.3. Social science case studies can contribute

The social science research methods (as explained in Chapter 4) that provided inputs in and analyzed the outcomes of the transfer process analyzed here (as presented in Chapters 5 to 8) was in line with recommendations by Hackmann and St. Clair (2012), mentioned in the introduction of this dissertation. They suggest that social science should provide research that supports and informs change processes towards greater equity and sustainability, and that social science has a responsibility to be innovative and stimulate creative thinking. Moreover, they find it important that social science takes the lead in developing a new transformative science of global change, including innovative methodological developments, such as trans-disciplinary approaches. Although the ambitions in this dissertation are more modest than this, the current research has provided an example of potential ways of doing research on and for social change, and some of the challenges and opportunities involved in such research.

The social science research at different steps of the transfer process from India to Kenya has highlighted the importance of emphasizing the social aspects and human dimensions of efforts for technological change, and shown the ongoing socio-technical dynamics and complexity of implementation of technologies. The analysis has also shown that social science inputs such as described in this dissertation have a potential to stimulate the learning processes, both within and between specific change initiatives. Examples include strengthening the focus on contextual factors, the social organization socio-technical configurations, the roles and challenges of the actors and the general embedding of socio-technical systems in social life as well as the impact of social life on socio-technical systems.

Social science research is a wide and diverse field. For the transfer process carried out in this case the use of a broad framework of analysis with weight on qualitative methods contributed to comprehensive understandings of socio-technical innovations in their context, including the perspectives of people in the villages. Interestingly, social science contributions/trans-disciplinary work in socio-technical innovation might partly be seen as a way of trying to deal with the uncertainty that involved actors constantly try to deal with (Russell and Williams 2002). The research can shed light on the perceptions, needs and ideas of potential users and the ways in which they relate to socio-technical changes, monitor emerging outcomes, analyze reasons and suggest changes.

There are different ways in which relevant examples in other places might be studied in order to transfer knowledge and experiences in practice. In the literature on technology transfer in the South there is very little attention to the question of how the "recipients" can investigate relevant lessons generated by people in other places and countries. In the literature on inter-local learning, the ways of obtaining knowledge about other projects include reading of handbooks and reports about projects, going for study visits, use of internet forums and interaction with other project implementers in workshops (Raven et al. 2008). This research indicates that conducting a comprehensive case study of the examples is also relevant, and can make a difference for the subsequent transfer process and its outcomes. Moreover, trans-disciplinary work and thereby heterogeneous teams has the potential to grasp different dimensions of socio-technical change to a larger extent than neither the social scientists, nor the practitioners could have achieved alone, as in the case studies on the Indian and Kenyan energy systems.

The social science case study in India added to the one week study visit in that it went in depth and studied the cases in detail according to the case study framework, and gradually improved the understanding of underlying mechanisms of the observed situation. The research changed the first impression and gave a better picture of the roles of the actors involved, what their challenges were, how they perceived their own situation and what motivated them, as well as how different people affected the functioning of the entire system and why. Some of the tacit knowledge might have been grasped by combining a wide range of data. Moreover, the case study provided insights in important details of the socio-technical configurations and organizational forms, as presented in Chapter 5.

In Kenya, the social science research on the local, socio-cultural context before implementation of the Ikisaya Energy Centre was a central element of the process of "translating" and "re-contextualizing" knowledge and experience from elsewhere. The social science results became mixed with the other ways of forming the team's understanding of this context, including practitioners' observations and local actors' contributions. After implementation of the practical project, the social science contributions helped monitor and analyze the outcomes and make improvements, also here in combination with the other actors' contributions.

The trans-disciplinary cooperation was seen as valuable by the participants. One of the experienced practitioners in the team expressed that the cooperation with social scientists was valuable because the practitioners (usually technical experts) are often "…deeply involved in the timely execution of the project, especially considering the challenging working conditions in remote and rural areas…" and that the social scientists can bring in other important perspectives. He referred in particular to the attention to community engagement, assessment of community dynamics and the needs and requirements of users from a non-technical perspective, as well as critical evaluation of the outcome of the project.

According to this research, social science contributions have the potential to play a direct role for spatial transfer of innovations and socio-technical change in practice. Social scientists can also act as catalysts and/or leaders for deliberate social transformation in real life settings through action research. However, this role of a social scientist depends on cooperation with other societal actors including skilled and experienced practitioners. It also depends on time and resources available, and the comprehensiveness of the activity. Leadership in an academic-practical project might require engagement and responsibilities that go far beyond what social scientists normally do and create dilemmas between time spent on academic tasks and other tasks. This is typical for action research (Kalleberg 1992, Herr and Anderson 2005, Karlsen and Larrea 2014). Thereby, such research is also likely to meet challenges in existing frames of research and project periods and require considerable additional voluntary contributions of time and resources.

9.3. How can the learning processes be organized?

The answers to the first research question have emphasized the importance of creating good learning processes in planning, implementation, sustaining, up-scaling and institutionalization of decentralized electricity systems. Similarly, the answers to the second research question have shown that learning and innovation can be both a means for and a consequence of spatial transfer of innovations. The answers to the two research questions have thereby been relevant for a theoretical question that was identified as a gap in the theoretical literature presented in Chapter 2, and that underpins the entire dissertation. This question is *which conditions are supportive to learning and innovation in practical efforts for socio-technical changes?* In other words, the question concerns how the learning process is designed or organized. Some additional points on this issue of learning and innovation in spatial transfer and socio-technical experimentation are presented below.

As mentioned in Chapter 2, the literature on socio-technical change and transitions has more recommendations on *what* the socio-technical experiments can and should do than *how* they might be organized in order to achieve a fruitful learning process. This question on *how* represents a step downward or inwards, from the focus on niche-internal processes to the experiment, as mentioned in Chapter 2, since an experiment is not the same as a niche. The question is at the same time expected to have relevance for how the broader socio-technical innovation processes (niche developments) are stimulated, as explained in Chapter 2. The chapter also suggested that learning is the most important of the three niche internal processes. Seen from the perspective of the individual, pioneering activity, learning is the dominating, long-term process, while formation of networks and expectations are more like side-effects in addition to being part of the starting point for the activity. An important part of the learning process is also the active diffusion of learning in terms of knowledge sharing, and attempts to influence institutions.

The conclusions suggested here are especially relevant for socio-technical experiments with certain similarities with the Indian and Kenyan projects, but might have some relevance also for socio-technical experiments in general. As mentioned, the Indian case has been seen as a sustainability experiment driven by government actors, where social goals (affordable light and other electricity services for people in poor, remote, electrified villages) were an important part of the motivation. The Kenyan case has been seen as a hybrid between a bounded socio-technical experiment and grassroots innovation, where a comprehensive, spatial transfer process was part of the activity. Some points on conditions or mechanisms that facilitate learning in practical projects are provided below.

9.3.1. Learning on what?

Before discussing the organization of socio-technical experiments for vigorous learning it might be useful to look at what the learning can be about in such activities. Second order learning has been pointed out as a key to socio-technical innovation towards sustainability (Kemp et al. 1998), and thereby given higher value than first order learning, due to the radical changes that are required in society. According to Schot and Geels (2008), the body of research on niche formation has shown that learning processes contribute to strengthening the niches if there is second order learning, which enables changes in cognitive frames and assumptions. However, incremental (or first order) learning seem to be important in the internal learning process in the individual experiment, while it can contribute to second order learning at the level of niches, in the context of established regimes (Brown and Vergragt 2008, Byrne 2009).

In the projects studied here, first order learning (incremental learning) dominated at the project level while the projects contributed to second order learning in a larger perspective. The Sunderban pilot project, for instance, contributed to second order learning by paving the way for further work on solar mini- and micro-grids in India and elsewhere. However during the project itself, the weight was on incremental learning as shown in Chapter 5. The Kenyan case, at the same time as having an impact on system-innovation in the Kenyan solar PV sector (or niche), comprised a process of incremental learning both during the comprehensive phase of developing the socio-technical design and during the years after the start of operations. The follow-up projects through a simpler model also constituted incremental steps. Most of this dissertation therefore exemplifies what incremental learning can be and how it may be facilitated, in addition to what such learning can be about. It shows that such learning is important for what kinds of socio-technical designs that are developed and by whom, and thereby the directions that may be taken by actors who attempt to contribute to system innovation for future sustainability.

Second order learning inside the individual experiment (such as questioning underlying assumptions) in the two cases could have been for instance to ask whether the solar PV technology is suitable, whether the village-level is suitable (compared with national level grid extension and household solutions), whether electricity is important for people, whether economic self-sustenance of the local project should be a goal, whether decentralized infrastructure is feasible and useful, or whether the current solutions are better for the people after all, than kerosene, diesel, etc. For the Sunderban case for instance, such questions related to use of other technologies in hybrid systems with solar PV to deal with the low solar radiation during the monsoon season. For the Ikisaya case, some such questions were discussed by the project team, but the focus was mainly on the details of how a specific promising solution (village-level solar power provision) can be made feasible and useful. While working on this issue, the team members as well as observers also learned about these broader questions (and thus probably influenced the expectations for the future).

In the Indian and Kenyan projects, learning took place in three broad areas for project team members or implementers and for different local actors. Firstly, learning clearly took place on innovative socio-technical designs and the variety of factors that influenced their actual functioning, resulting electricity access, and replication. Some of these aspects were of a relatively intangible type, such as motivation, gender roles, leadership, trust, creativity, economic incentives, and control mechanisms. This learning was important for the pilot projects and thereby for later activities that the lessons would be transferred to. Secondly, learning took place on mutual integration between socio-technical designs and social context, benefitting the specific projects and later replication. Thirdly, learning took place on the kinds of visions, objectives and qualities that are desirable and realistic for village-level electricity projects, highlighting difficult dilemmas that need further work, as mentioned earlier in this chapter. All these kinds of learning were important for the understanding of how village-level power supply can be socially organized. The different "learning mechanisms" presented below mostly have relevance for all these three aspects.

9.3.2. Learning through co-design and co-generation of knowledge

This research highlights that an important part of the learning process in socio-technical experiments is the activity of finding out *how the socio-technical designs should be shaped;* i.e. which options can be possible and which ones should be chosen. Such socio-technical design processes take place before, but also during and after actual start-up of practical project activities at the local level. The kinds of strategies applied in such design processes influence the kinds of ideas for the configuration of social and technical elements that are developed, and the abilities of different actors to influence broader socio-technical innovation. The socio-technical design strategies determine which solutions are developed and which pathways towards future equity and sustainability might be opened up and tested, including different ways of organizing resource use, production, consumption and social distribution of wealth.

Several factors that are likely to play a role for learning in socio-technical experiments in general and during the process of developing and changing socio-technical designs in particular have already been pointed out in relation to the two main research questions. These include the attention to users' practices and innovation, the role of flexible socio-technical designs (or configurations) that allow for creativity, opportunities and willingness of project implementers to change course underway, and the role of social science contributions. The importance of facilitating processes of integration between social context and socio-technical designs has also been pointed out. Some additional and related factors are discussed below.

Development of innovative socio-technical designs can take place through interaction between different kinds of participants in a common struggle to solve problems. Such "co-design" processes and co-generation of knowledge can be organized in inclusive ways, and social science research can give voice to those who are not raising their voice in public. Valuable learning processes might be generated if there is time and resources for stepwise, adaptive processes. This can allow for gradual development of ideas for socio-technical designs, based on gradually increased understanding of contextual factors, users' needs, and gradually emerging ideas and solutions to problems met underway. The inclusion of potential users and their points of view during and after planning and implementation is not only useful for strengthening acceptance and adoption by making the technology fit with their needs, practices and interests. It is also important in order to increase the inclusiveness and distributional aspects of the socio-technical change as pointed out by Avelino (2009) (based on case studies in Europe).

A key challenge in broad, participatory processes is that the end users' suggestions, wishes and needs might not be possible to fulfill, and this may lead to unfulfilled expectations and dissatisfaction. Communication and explanation is therefore important, during and after implementation, not only before. Moreover, there is a fine line between user innovations and "unruly" users who undermine the system, but the "unruly" users point to weaknesses of the system, and thereby necessitates further social and technological innovation. In the Sunderban for instance, there was creativity in how the people who were connected to the mini-grids managed to distribute electricity spatially and socially to those who were not connected (either due to the limited spatial outreach of the mini-grids, or due to inability to afford a connection). People with a connection charged devices for others (including portable batteries) or made a "by-pass" to neighbors (illegal connections) and thereby also made business on such activities. A lesson from this could be to attempt designing systems that could enable similar activities in regulated ways, especially charging businesses. This would depend on solving issues of power production capacity, metering and payment.

9.3.3. Learning through inspiration and commitment

The role of inspiration and commitment on all levels in socio-technical experimentation might be a neglected aspect in theories on socio-technical change. Most likely, it is some of the "energy" that drives the change. Persistence and stubbornness may also be important ingredients in the learning processes. Moreover, supporting Avelino (2009), leaders in challenging group processes should have a strong, intrinsic motivation for the work in order to drive the process forward through challenging times. This was observed at the local level in Ikisaya through the leadership taken by central individuals, and experienced in the leadership of the overall Indian and Kenyan projects.

Committed and passionate actors have sometimes been pointed out as a kind of success factor that makes a project difficult to replicate Shrank (2008). When team partners in the Kenyan project realized the role of the passionate leader of the Sunderban projects in India, they discussed whether it can be possible to repeat something that has been driven by a committed and engaged individual with strong visions. The person was also a government official with influence on policies and access to financial and other resources. However, already at that time it could be seen that there was also a Kenyan individual with some of the same characteristics and positioning, as explained earlier. Moreover, inspiration and commitment was already present in the project team.

This research indicates that inspiration, enthusiasm and commitment might be a "replicable" (and infectious) factor to a larger extent than what is sometimes assumed, and that such attitudes may not be rare. Inspiration and commitment is likely to be found both in remote poor villages, within government offices, consultants' realms, the private business sector, within academia and in any other field of activity, depending on individuals' freedom to work on something that is inspiring for them.

A potential source of inspiration and ideas is certainly learning from other projects. This can contribute to diversity in socio-technical designs, as the learning process from India to Kenya suggests. The opportunity to go to the Sunderban and see solar mini-grids for the first time was an exciting and inspiring experience for all the participants. Moreover, learning about challenges met in other projects showed that struggles to solve unexpected problems might be a normal part of innovative endeavors.

Factors that inspired other community members who got involved, included the possibility to achieve improvements in the village, including access to electricity and the opportunity to utilize the local, abundant solar resource. Local employment opportunities were also regarded as important, and people also hoped that the project could lead to other changes, including improved education for their children and income generation through processing local forest products. These visions and expectations were higher than what the team could be able to fulfill, and led to vigorous discussions in the project team on how the Ikisaya model design could accommodate people's suggestions. The problematic side of inspiration and high expectations is disappointment, which requires prevention, and handling when it occurs. Moreover, inspiration should not lead to overly optimistic plans, persuasion of partners to join, rushed or poorly planned implementation processes, and little thought of long-term problem solving. A humble approach is probably equally important as inspiration.

The inspiration for the project team was influenced by different kinds of visions for positive societal changes, as explained in Chapter 6. The most important visions for the team's learning process were the objectives for the qualities of the project (broad access, economic sustainability, well-functioning operation and maintenance, gender and context sensitivity, modest investment level and replicable system.) These objectives gave direction at the same time as being broad enough to inspire creativity on socio-technical designs. A range of different socio-technical designs could potentially fulfill them, whether mini-grid or "energy center models" or other kinds of models. Most of the choices made underway in the long term learning process analyzed here were influenced by these visions or objectives, which to a large extent concerned human, organizational and context-related dimensions of the systems and the chances for replication.

As suggested in the theoretical literature, a sense of urgency can be important for the learning process (Brown and Vergragt 2008). Urgent needs for light in remote communities inspired the Sunderban projects. Similarly, in the case of Ikisaya, cooperation with people who had strong needs for the new solutions, and a strong willingness in the team to understand their general challenges, provided a sense of urgency. The uncertainty and risk of failing to fulfill their needs made the project team to thoroughly consider how people's need for electricity services could be met in ways that could fit within the constraints of their general living conditions, and within the various limitations for the socio-technical design. Neither the Indian nor the Kenyan projects fully achieved these goals and the long term destiny of the Ikisaya cluster remains unknown. However, the struggles to achieve such goals and their partial achievement both in the Sunderban and the Ikisaya projects generated intensive learning processes on factors that influence functioning, usefulness and viability of village-level solar provision.

9.3.4. Learning through shifting roles and contrasting perspectives

Another kind of factor that might enhance learning and innovation in socio-technical experimentation is shifting roles for the actors, and other conditions that provide contrasting perspectives. One example is shifting from being observer to participant to observer again, as seen in the research team's shift from studying the Sunderban case, to having the responsibility to do similar activities (and solve similar challenges) in Kenya, and thereafter analyzing and sharing results (shifting between two kinds of constructive research mentioned in Chapter 1). This is one of the ways in which international knowledge sharing or other spatial transfer of innovation can stimulate learning for socio-technical change.

Shifting between academic tasks and the practitioners' tasks also provides contrasting perspectives. For an academic it can be a strong eye opener to try what it is like to be in the practitioners' shoes, enhancing a deeper understanding of practitioners' challenges and the socio-technical dynamics in a community energy project, or other sustainability experiments or grassroots innovations. Mutual challenging between practitioners' hands-on experience and social scientist's more abstract approaches can also stimulate new ways of thinking. A social science led, trans-disciplinary project might be very different from the projects that the practitioners are used to, and create friction as well as humor and friendly rivalization. For social scientists who analyze ways of embedding technologies in societal contexts, the collaboration with engineers and other practitioners might be much more fruitful than collaboration with academic researchers in the field of development of technology hardware, for instance.

Learning is also generated through the striking contrasts between the ambitious visions and the necessary struggles on practical details, uncertainties, disappointments, failing, trying again, being forced to resign on some parts, refusing to give up, and trying over again.

Working closely with others toward common goals, having "team feeling", contrasts with mutual challenging, disagreement on details, tensions and mutual blaming that may come out of the inevitable disappointments and failures. Learning also takes place through trying to understand another person's perspectives. In the Solar Transitions case, some of the disagreements between team members, and related mutual learning were related to variations in political views, which came to the fore through differing views on the importance of private sector actors in village-level power provision. Individuals sometimes shifted between different arguments for and against the potential and feasibility of commercial versus government supported solutions, disagreeing with the "last speaker" because they saw the possibilities and constraints of both.

An observation through the action research in Ikisaya village, was that when facing the realities of people in vulnerable situations, despite the project team members being the most powerful part of the collaboration, there was also a sense of being powerless due to the strong need for many kinds of changes in the villages. Access to electricity was a kind of change that was welcomed by community members, but there were several other changes that would be more important for them, such as more jobs, better incomes, more and cheaper food and better water supply, which the project team was not able to assist with.

An activity of systematic and comprehensive spatial transfer of innovations can provide a special opportunity for close collaboration between team members representing different world regions, different kinds of expertise and academic disciplines, different project experience, different genders and life experience. In this case this was found to contribute to complementary ideas and skills for developing and trying out socio-technical designs in cooperation with societal groups.

The importance of mixed teams in socio-technical experimentation has been pointed out by several authors, including Brown and Vergragt (2008) and Loorbach and Rotmans (2010) who mention the need for actors with different perspectives on a problem, representing different organizations, communities of practice and institutional affiliations. This research supports that a diversity of team members is useful, and shows that a team can be heterogeneous in different ways, through different kinds of similarities and differences between team members. In the case of the transfer activity analyzed here, similarities between team members included common interests and similar visions and goals for the project from the outset (most important), informal ways of interacting, and age group (33-56). All the team members were "niche actors" in the sense that they were interested in strengthening the niche of the solar PV use in Kenya and elsewhere. The government official who entered the team on his own initiative was a "mixed" actor because his daily work was in conventional power supply, but in a decentralized part based on diesel generators.

The differences between team members in this case included the countries of origin (three different world regions), context for earlier education and work experience, socio-cultural and religious backgrounds and academic versus non-academic background. Other differences were personal economy, familiarity with the remote villages, interest in collecting and analyzing data of various kinds, and committedness to the project. These differences influenced the learning process by affecting the communication, cooperation, and mutual learning between team members, mostly positively. Personality, attitude and personal "match" between team members influenced relations, communication and cooperation more than other characteristics. Learning between and together with team members was at least as important for the international knowledge sharing as learning between projects and countries, as shown by the long term learning process going on after the case study in India.

According to this research, South-South-North learning can provide a rich diversity of perspectives and contrasts that are stimulating for learning processes. At the same time, the team members' country of origin may not play a strong role for the ways in which people contribute to the common work. In the learning process analyzed here, mutual and joint learning was the plan. Participants from the North were not involved in order to do "capacity building" in the South. As commented by one of the Kenyan team members: "The beauty of the Solar Transitions project is that we are all learning together." Importantly, the new knowledge obtained by the involved people from different parts of the world as well as the new linkages between actors (and the mutual capacity building) was created by the long-term collaboration between team members to solve common tasks in research and practice.

The potential of such learning processes to affect replication, diffusion of learning from the experiment and wider up-scaling has been mentioned in the first part of the chapter. According to this research, more attention to the individual experiments and their substance could potentially contribute to broader learning processes, although this might sound like a paradox. The case studies in India and Kenya illustrate the importance of a diversity of socio-technical experiments and forms of innovation, social as well as technological as pointed out in the literature, both for building up alternative socio-technical systems in niches, nationally and internationally, and for the societal learning processes on what the models can look like and what sustainability can and should be (Stirling 2009, Leach et al. 2010).

9.4. Final remarks

This study has explored the relevance of a socio-technical systems perspective for the two topics of this dissertation; electricity access and spatial transfer of innovations. According to this research, concepts of socio-technical change and systems can be useful for the analysis of both. Theoretical concepts were used in an open and flexible way, by bringing them in where they suited instead of structuring the analysis according to the theoretical concepts. This way of using theory allowed attention to a range of aspects of the local cases in villages and many characteristics of the transfer process at the same time as it helped focusing attention to important dynamics of socio-technical change. Structure for the analysis was obtained by "translating" a socio-technical systems perspective to a less abstract framework of analysis, designed for studying village-level (or community-level) infrastructures. The framework combined a strong focus on social and human dimensions with attention to systems thinking and technical and economic aspects.

Analyzing spatial transfer of innovations by the use of a socio-technical systems perspective helped seeing the learning and innovation processes involved, and how these might be created. It also helped articulating how the early phases of a transfer process might influence the rest of the process. Such a perspective provided understanding of how the organization of a transfer process might contribute to processes of mutual adaptation between society and technology in different places.

Scholars in this field of research have called for increased territorial sensitivity of transition analysis, with more reflection on the spatial contexts and conditions as well as stronger acknowledgment of and attention to geographical diversity (Coenen et al. 2012). Although this dissertation is not a transition analysis, but rather an analysis of societal actors' attempts to strengthen emerging technological options, it might still be seen as a response to this call, because it looks at several aspects of socio-technical innovation.

One broad geographical theme found to be especially important for this research, was the gradual, mutual adaptation or embedding between technologies and social contexts in different localities in different, regions and countries. The analysis provided examples of how social and geographical contexts at different levels influence (or should influence) the design and functioning of infrastructures. The dissertation has shown that consideration of these aspects might be necessary in research and practice on how to achieve electricity access for all, and has demonstrated different ways in which they might be taken into account.

The research also shows that geographical diversity is more than a contextual factor that has to be taken into account in analysis of socio-technical change. It is also a valuable asset that can be taken advantage of in research and practice. This is because it creates a diversity of ideas and experiences, and thereby opportunities for learning between them. It is therefore important to bring in spatial and contextual dimensions to a larger extent in the field of socio-technical innovation, social transformation and international knowledge sharing.

An implicit assumption in this research has been that concepts of social learning and socio-technical change are relevant in different parts of the world, although they have mostly been applied to cases in European countries. Despite the societal differences between countries and world regions, many of the insights of the socio-technical systems perspective must necessarily provide insights in social and technological changes all over the world. Societal actors (individual and collective) gradually develop new ways of using technologies through trying and learning, influenced by uncertainties, unexpected outcomes and established social structures. The dissertation shows that increased focus on similarities and general characteristics of human societies as much as differences can contribute to joint and mutual research and learning processes without ignoring global injustice and local inequality. Innovative approaches to international cooperation, knowledge sharing and joint development and testing of new ideas, are likely to be necessary parts of solving the global challenge of providing electricity to all.

Appendix 1: Photos from India

Photo 1. Portable lanterns plugged in for charging inside a solar charging station.

Photo 2. A home with a small solar PV panel on the roof, as part of a solar home system of 60 W installed capacity.

Photo 3. The solar PV arrays of a solar mini-grid system of 110 kW installed capacity in the Sunderban Islands.

Photo 4.Gridlines of a solar mini-grid in the Sunderban Islands.

Photo 5. The operator of one of the solar mini-grids in front of an inverter and charge controller.

Photo 6. People of Sagar Island in the Sunderban Islands.

Appendix 2: Photos from Kenya

Photo 7. Ikisaya Energy Centre during installation.

Photo 8. Studying by light from a lantern rented at Ikisaya Energy Centre. (Photo: Lan Marie Berg).

Photo 10. Inverters and charging controllers at Ikisaya Energy Centre.

Photo 9. The Indian lanterns plugged in for charging at Ikisaya Energy Centre.

Photo 11. The IT room at Ikisaya Energy Centre.

References

Abdullah, S. & Markandya, A. (2012). Rural electrification programmes in Kenya: Policy conclusions from a valuation study. *Energy for Sustainable Development*, 16 (1): 103-110.

Ahlborg, H. & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique – Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy*, 61 (0): 117-124.

Ahlborg, H. (2015). *Walking along the lines of power. A systems approach to understanding co-emergence of society, technology and nature in processes of rural electrification. PhD thesis.* Göteborg, Sweden: Chalmers University of Technology, Department of Energy and Environment.

Ahlborg, H. & Sjöstedt, M. (2015). Small-Scale Hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages. *Energy Research and Social Science*, 5.

Alzola, J. A., Vechiu, I., Camblong, H., Santos, M., Sall, M. & Sow, G. (2009). Microgrids project, Part 2: Design of an electrification kit with high content of renewable energy sources in Senegal. *Renewable Energy*, 34 (10): 2151-2159.

Andersen, K. S. (2010). *Enlightenment and empowerment through power and light? - From theory to practice.* Oslo, Norway: University of Oslo, Masters Thesis. Centre for Development and Environment.

Arentzen, M., Kemp, R. & Luiten, E. (2002). Technological change and innovation for climate protection: The governance challenge. In Kok, M. T. J., Vermeulen, W., Faaij, A. & de Jager, D. (eds) *Global warming and social innovation. The challenge of a climate-neutral society*, p. 242. London: Earthscan.

Avelino, F. (2009). Empowerment and the challenge of applying transition management to ongoing projects. *Policy Sciences*, 42 (4): 369-390.

Avelino, F., Bosman, R., Frantzeskaki, N., Akerboom, S., Boontje, P., Hoffman, J., Paradies, G., Pel, B., Scholten, D. & Wittmayer, J. (2014). The (Self-)Governance of Community Energy: Challenges & Prospects. DRIFT practice brief nr. PB 2014.01. Rotterdam: DRIFT.

Bell, M. & Albu, M. (1999). Knowledge Systems and Technological Dynamism in Industrial Clusters in Developing Countries. *World Development*, 27 (9): 1715-1734.

Bellanca, R., Bloomfield, E. & Rai, K. (2013). *Delivering energy for development : models for achieving energy access for the world's poor*. Rugby, UK: Practical Action Publishing.

Berg, L. M. N. (2014). *Sunshine in Ikisaya: Exploring a research-introduced social enterprise and its potential to provide basic electricity services and to reduce vulnerability in a Kenyan village*. Norway: University of Oslo, Master thesis. Centre for Development and the Environment.

Berkhout, F., Angel, D. & Wieczorek, A. J. (2009). Asian development pathways and sustainable socio-technical regimes. *Technological Forecasting and Social Change*, 76 (2): 218-228.

Berkhout, F., Verbong, G., Wieczorek, A. J., Raven, R., Lebel, L. & Bai, X. (2010). Sustainability experiments in Asia: innovations shaping alternative development pathways? *Environmental Science & Policy*, 13 (4): 261-271.

Bhattacharyya, S. C. (2007). Sustainability of power sector reform in India: what does recent experience suggest? *Journal of Cleaner Production*, 15 (2): 235-246.

Bhattacharyya, S. C. & Srivastava, L. (2009). Emerging regulatory challenges facing the Indian rural electrification programme. *Energy Policy*, 37 (1): 68-79.

Bhattacharyya, S. C. (2010). Shaping a sustainable energy future for India: Management challenges. *Energy Policy*, 38 (8): 4173-4185.

Bhattacharyya, S. C. (2012). Review of alternative methodologies for analysing off-grid electricity supply. *Renewable and Sustainable Energy Reviews*, 16 (1): 677-694.

Bijker, W. & Law, J. (1994). General introduction In Bijker, W. & Law, J. (eds) *Shaping technology, builiding society: studies in sociotechnical change*. Cambridge, MA: Massachusetts Institute of Technology Press.

Bridge, G., Bouzarovski, S., Bradshaw, M. & Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy*, 53: 331-340.

Brown, H. S., Vergragt, P., Green, K. & Berchicci, L. (2003). Learning for Sustainability Transition through Bounded Socio-technical Experiments in Personal Mobility. *Technology Analysis & Strategic Management*, 15 (3): 291-315.

Brown, H. S. & Vergragt, P. J. (2008). Bounded socio-technical experiments as agents of systemic change: The case of a zero-energy residential building. *Technological Forecasting and Social Change*, 75 (1): 107-130.

Byrne, R., Smith, A., Watson, J. & Ockwell, D. (2011). Energy Pathways in Low-Carbon Development: From Technology Transfer to Socio-Technical Transformation. *Working Papers from the STEPS Centre*. Brighton, UK: University of Sussex.

Byrne, R. P. (2009). *Learning drivers – Rural electrification regime building in Kenya and Tanzania*. UK: PhD dissertation. University of Sussex.

Cabraal, A., Cosgrove-Davies, M. & Schaffer, L. (1996). Best practices for photovoltaic household electrification: Lessons from experiences in selected countries. Washington, USA: World Bank.

Camblong, H., Sarr, J., Niang, A. T., Curea, O., Alzola, J. A., Sylla, E. H. & Santos, M. (2009). Micro-grids project, Part 1: Analysis of rural electrification with high content of renewable energy sources in Senegal. *Renewable Energy*, 34 (10): 2141-2150.

CEEP. (2001). Off-grid renewable energy options for rural electrification in Western China. USA: Center for Energy and Environment Policy, University of Delawere.

Chakrabarti, S. & Chakrabarti, S. (2002). Rural electrification programme with solar energy in remote region–a case study in an island. *Energy Policy*, 30 (1): 33-42.

Chambers, R. (2008). *Revolutions in development inquiry*. London: Earthscan.

Chambers, R. (2012). Sharing and Co-generating Knowledges: Reflections on Experiences with PRA1 and CLTS2. *IDS Bulletin*, 43 (3): 71-87.

Chaudhuri, S. P. G. (2007). *Renewable Energy in the Sundarbans*. New Delhi, India: TERI Press.

Chaurey, A., Ranganathan, M. & Mohanty, P. (2004). Electricity access for geographically disadvantaged rural communities—technology and policy insights. *Energy Policy*, 32 (15): 1693-1705.

Chaurey, A. & Kandpal, T. C. (2006). A techno-economic analysis of solar home systems for decentralized rural electrification in India. *SESI Journal*, 16 (2): 1-21.

Chaurey, A. & Mohanty, P. (2007). Distributed generation and rural electrification in the Sundarbans. In Choudhuri, S. P. G. (ed.) *Renewable Energy in the Sundarbans*. India: The Energy and Resources Institute (TERI),.

Chaurey, A. & Kandpal, T. C. (2010). A techno-economic comparison of rural electrification based on solar home systems and PV microgrids. *Energy Policy*, 38 (6): 3118-3129.

Coenen, L., Raven, R. & Verbong, G. (2010). Local niche experimentation in energy transitions: A theoretical and empirical exploration of proximity advantages and disadvantages. *Technology in Society*, 32 (4): 295-302.

Coenen, L., Benneworth, P. & Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. *Research Policy*, 41 (6): 968-979.

Corsair, H. J. & Ley, D. (2008). *The commercialization of solar energy as a means for rural development*. IEEE Energy2030 Conference, 17-18 Novermber 2008, Atlanta, Georgia, USA.

Dewald, U. & Truffer, B. (2012). The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. *European Planning Studies*, 20 (3): 397-420.

Dubash, N. K. (2007). Electrifying rural India: The search for a viable and sustainable approach. In Panda, H. (ed.) *Governance of rural electricity systems in India*. New Delhi, India: Academic foundation.

Edquist, C. (2005). Systems of Innovations: perspective and challenges In Fagerberg, J., Mowery, D. C. & Nelson, R. R. (eds) vol. 181-208 *The Oxford Handbook of Innovation* Oxford, New York: Oxford University Press.

Engelstad, F., Grenness, C. E., Kalleberg, R. & Malnes, R. (2005). *Introduksjon til samfunnsfag: vitenskapsteori, argumentasjon og faghistorie*. Oslo: Gyldendal akademiske forlag.

Engelstad, P. H., Emery, F. E. & Thorsrud, E. (1970). *Teknologi og sosial forandring på arbeidsplassen: et eksperiment i industrielt demokrati*. Oslo: Tanum.

Eriksen, S. & Lind, J. (2009). Adaptation as a political process: adjusting to drought and conflict in Kenya's drylands. *Environmental Management*, 43 (5): 817-35.

Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D. A., Molefe, J. I., Nhemachena, C., O'Brien, K., Olorunfemi, F., Park, J., Sygna, L., et al. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development*, 3 (1): 7-20.

Eriksen, S. H., Klein, R. J. T., Ulsrud, K., Næss, L. O. & O'Brien, K. (2007). Climate change adaptation and poverty reduction: key interactions and critical measures. Report prepared for the Norwegian Agency for Development Cooperation (NORAD). Oslo: GECHS International Project Office.

ESCAP. (2005). *Energy services for sustainable development in rural areas in Asia and the Pacific: Policy and practice*. Energy Resources Development Series No. 40. New York: United Nations Economic and Social Commission for Asia and the Pacific.

ESMAP. (2001). Best Practice Manual: Promoting decentralized electrification investment. Washington, USA: World Bank.

Fagerberg, J. (2005). Innovation: A guide to the literature. In Fagerberg, J., Mowery, D. C., Nelson, R. R., Asheim, B. T., Bruland, K. & Grodal, S. (eds) *The Oxford handbook of innovation*. Oxford: Oxford University Press.

Fangen, K. (2010). *Deltagende observasjon*. Bergen: Fagbokforlaget.

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12 (2): 219-245.

Fuenfschilling, L. & Truffer, B. (2014). The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Research Policy*, 43 (4): 772-791.

GEA. (2012). *Global Energy Assessment: Toward a Sustainable Future. International Institute for Applied Systems Analysis. GEA Writing Team.* Cambridge, United Kingdom: Cambridge University Press.

Geels, F. & Raven, R. (2006). Non-linearity and Expectations in Niche-Development Trajectories: Ups and Downs in Dutch Biogas Development (1973–2003). *Technology Analysis & Strategic Management*, 18 (3-4): 375-392.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31 (8–9): 1257-1274.

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, 39 (4): 495-510.

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, 1 (1): 24-40.

George, A. L. & Bennett, A. (2005). *Case studies and theory development in the social sciences*. Cambridge, Massachusetts, London, England: MIT Press.

Giddens, A. (1989). *Sociology*. Cambridge, United Kingdom: Polity Press.

Gomm, R., Hammersley, M. & Foster, P. (2000). *Case study method: key issues, key texts*. London, UK: Sage Publications Ltd.

Government of West Bengal. (2004). West Bengal Human Development Report 2004. West Bengal, India: Development and Planning Department.
Greenwood, D. J. & Levin, M. (1998). *Introduction to action research. Social research for social change.* Thousand Oaks, London, New Delhi: SAGE Publications.
Grin, J., Rotmans, J. & Schot, J. (2011). On patterns and agency in transition dynamics: Some key insights from the KSI programme. *Environmental Innovation and Societal Transitions*, 1 (1): 76-81.
Grübler, A. & Nakićenović, N. (1991). Long Waves, Technology Diffusion, and Substitution. *Review (Fernand Braudel Center)*, 14 (2): 313-343.
GTZ. (2009). Kenya's Solar Energy Market - Target Market Analysis Berlin, Germany: Project Development Programme (PDP) East Africa. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) on behalf of the German Federal Ministry of Economics and Technology (BMWi).
Gulati, M. & Rao, M. Y. (2007). Corruption in the electricity sector. A pervasive scourge. In Campos, J. E. & Pradhan, S. (eds) *The Many Faces of Corruption: Tracking Vulnerabilities at the Sector Level*. Washington, D.C.: World Bank.
Hackmann, H. & St. Clair, A. L. (2012). Transformative Cornerstones of Social Science Research for Global Change. Paris, France: International Social Science Council.
Halsnæs, K., Shukla, P., D.:, A., Akumu, G., Beale, R., Edmonds, J., Gollier, C., Grübler, A., Ha Doung, M., Markandya, A., et al. (2007). Framing issues. In Metz, B., Davidson, O. R., Bosch, P., Dave, R. & Meyer, L. (eds) *IPCC, 2007: Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on climate Change*, pp. 117-167. Cambridge, United Kingdom: Cambridge University Press.
Hammersley, M. & Atkinson, P. (2007). *Ethnography: principles in practice*. Third Edition ed. London: Routledge.
Hanson, J. (2013). *Dynamics of innovation systems for renewable energy technology: The role of post-introduction improvements*. PhD dissertation. Center for Technology, Innovation and Culture, Faculty of Social Scinences, University of Oslo.
Hargreaves, T., Hielscher, S., Seyfang, G. & Smith, A. (2013). Grassroots innovations in community energy: The role of intermediaries in niche development. *Global Environmental Change*, 23 (5): 868-880.
Haugen, H. Ø. (2013). *Changing markets from below, Trade and the movement of people between China and Africa*. Norway: University of Oslo,, Department of Sociology and Human Geography.
Herr, K. & Anderson, G. L. (2005). *The Action Research Dissertation: A Guide for Students and Faculty*. London, United Kingdom: Sage Publications.
Hielscher, S., Seyfang, G. & Smith, A. (2011). Community Innovation for Sustainable Energy. Norwich, UK.
Hoekman, B., Maskus, K. E. & Saggi, K. (2004). *Transfer of Technology to Developing Countries: Unilateral and Multilateral Policy Options*. Policy Research Working Papers, vol. World Bank Policy Research Working paper 3332, June 2004: The World Bank.
Hofman, P. S. & Elzen, B. (2010). Exploring system innovation in the electricity system through sociotechnical scenarios. *Technology Analysis & Strategic Management*, 22 (6): 653-670.
Hoogma, R., Kemp, R., Schot, J. & Truffer, B. (2002). *Experimenting for sustainable transport: The approach of strategic niche management*. London and New York: Spon Press.
Hubbard, P., Kitchin, R., Bartley, B. & Fuller, D. (2002). *Thinking geographically. Space, theory and contemporary human geography*. London - New York: Continuum.
Hughes, T. P. (1983). *Networks of power: electrification in western society, 1880-1930*. Baltimore: Johns Hopkins University Press.
Huseby, V. B. (2012). *Exploring Trust as a Function in Common Resources Management*. Oslo, Norway: University of Oslo, Masters Thesis. Institutt for sosiologi og samfunnsgeografi.

IEA. (2011). Energy for all: Financing access for the poor. Special excerpt of World Energy Outlook 2011, First presented at the Energy for All conference in Oslo, Norway in October 2011: OECD/IEA.

IFC. (2012). From Gap to Opportunity: Business Models for Scaling Up Energy Access USA, Washington

Ilskog, E. (2008). Indicators for assessment of rural electrification—An approach for the comparison of apples and pears. *Energy Policy*, 36 (7): 2665-2673.

Ilskog, E. & Kjellström, B. (2008). And then they lived sustainably ever after?—Assessment of rural electrification cases by means of indicators. *Energy Policy*, 36 (7): 2674-2684.

Iniyan, S. & Jagadeesan, T. R. (1997). On the development of a reliability based optimal renewable energy model for the sustainable energy scene in India. *International Journal of Ambient Energy*, 18 (3): 153-164.

Jacobson, A. (2007). Connective Power: Solar Electrification and Social Change in Kenya. *World Development*, 35 (1): 144-162.

Jacobson, A. E. (2004). *Connective power: Solar electrification and social change in Kenya. PhD dissertation*. USA: University of California, Berkely.

Jain, A., Choudhury, P. & Ganesan, K. (2015). Clean, Affordable and Sustainable Cooking Energy for India. Possibilities and Realities beyond LPG. New Delhi, India.

Jolly, S., Raven, R. & Romijn, H. (2012). Upscaling of business model experiments in off-grid PV solar energy in India. *Sustainability Science*, 7 (2): 199-212.

Joseph, K. L. (2010). The politics of power: Electricity reform in India. *Energy Policy*, 38 (1): 503-511.

Kalleberg, R. (1992). *Konstruktiv samfunnsvitenskap: en fagteoretisk plassering av "aksjonsforskning"*. Rapportserien ved Sosiologi, vol. 24. Oslo: Institutt for sosiologi, Universitetet i Oslo.

Kalleberg, R. (1993). Konstruktiv samhällsvetenskap. In Holmer, J. & Starrin, B. (eds) *Deltagarorienterad forskning*, pp. 27-51. Lund, Sweden: Studentlitteratur.

Kalleberg, R. (2009). Can normative disputes be settled rationally? . In Cherkaoui, M., Hamilton, P. & Boudon, R. (eds) *Raymond Boudon: a life in sociology: essays in honour of Raymond Boudon*, pp. Vol. 2, pp. 251-269. Oxford, UK: The Bardwell Press.

Karekezi, S. (2002). Poverty and energy in Africa - A brief review. *Energy Policy*, 30 (1): 915-919.

Karlsen, J. & Larrea, M. (2014). *Territorial development and action research: innovation through dialogue*. Farnham, England: Gower Publishing Limited.

Kemp, R. (1994). Technology and the transition to environmental sustainability: The problem of technological regime shifts. *Futures*, 26 (10): 1023-1046.

Kemp, R., Schot, J. & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10 (2): 175-198.

Kemp, R., Parto, S. & Gibson, R. B. (2005). Governance for sustainable development: Moving from theory to practice. *International Journal of Sustainable Development*, 8 (1/2): 12 - 30.

Kindon, S. (2010). Participatory Action Research. In Hay, I. (ed.) *Qualitative research methods in human geography*. Oxford, UK and Canada: Oxford University Press.

Kirubi, C. (2009). *Expanding Access to Off-grid Rural Electrification in Africa: An Analysis of Community-based Micro-grids in Kenya*. USA: PhD dissertation. University of California, Berkeley.

Kirubi, C., Jacobson, A., Kammen, D. M. & Mills, A. (2009). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, 37 (7): 1208-1221.

Kumar, A., Mohanty, P., Palit, D. & Chaurey, A. (2009). Approach for standardization of off-grid electrification projects. *Renewable and Sustainable Energy Reviews*, 13 (8): 1946-1956.

Leach, M., Scoones, I. & Stirling, A. (2010). *Dynamic sustainabilities: technology, environment, social justice*. London: Earthscan.

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A. C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., et al. (2012). Transforming Innovation for Sustainability. *Ecology and Society*, 17 (2).

Levin, M. & Ravn, J. E. (2007). Involved in praxis and analytical at a distance. *Systemic Practice and Action Research*, 20 (1): 1-13.

Lincoln, Y. S. & Guba, E. G. (2000). The only generalization is: There is no generalization. In Gomm, R., Hammersley, M. & Foster, P. (eds) *Case study method*, pp. 27-44. London: Sage Publications Ltd.

Loorbach, D. (2007). *Transition Management* Utrecht, Netherlands: International Books.

Loorbach, D. & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, 42 (3): 237-246.

MacKenzie, D. & Wajcman, J. (eds). (1999). *The Social shaping of technology*. Maidenhead, USA: Open University Press.

Mansvelt, J. & Berg, L. D. (2010). Writing qualitative geographies, constructing meaningful geographical knowledges. In Hay, I. (ed.) *Qualitative reserach methods in human geography*, pp. 333-355. Ontario: Oxford University Press.

Mapfumo, P., Adjei-Nsiah, S., Mtambanengwe, F., Chikowo, R. & Giller, K. E. (2013). Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development*, 5: 6-22.

Martinot, E., Sinton, J. E., Haddad & M., B. (1997). International technology transfer for climate change mitigation and the cases of Russia and China. *Annual Review of Energy and the Environment*, 22 (1): 357-401.

Maskus, K. E. (2004). Encouraging International Technology Transfer. *Issue Paper*. Geneva, Switzerland.

Meadowcroft, J. (2011). Engaging with the politics of sustainability transitions. *Environmental Innovation and Societal Transitions*, 1 (1): 70-75.

Metz, B., Davidson, O. R., Martens, J.-W., Rooijen, S. N. M. v. & McGrory, L. V. W. (2000). Methodological and Technological Issues in Technology Transfer - A special report of IPCC Working Group II. Published for the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: University of Cambridge.

Mielnik, O. & Goldemberg, J. (2002). Foreign direct investment and decoupling between energy and gross domestic product in developing countries. *Energy Policy*, 30 (2): 87-89.

Miller, D. (2009). *Selling solar: the diffusion of renewable energy in emerging markets*. London: Earthscan.

Millinger, M., Mårlind, T. & Ahlgren, E. O. (2012). Evaluation of Indian rural solar electrification: A case study in Chhattisgarh. *Energy for Sustainable Development*, 16 (4): 486-492.

Mitchell, J. C. (2000). Case and Situation Analysis. In Gomm, R., Hammersley, M. & Foster, P. (eds) *Case study method: Key issues, key texts*. London, UK: Sage Publications Ltd.

Moharil, R. M. & Kulkarni, P. S. (2009). A case study of solar photovoltaic power system at Sagardeep Island, India. *Renewable and Sustainable Energy Reviews*, 13 (3): 673-681.

Mosberg, M. (2013). *Solar energy and sustainable adaptation to climate variability and change - A case study from Ikisaya village, Kenya*. Ås, Norway: Norwegian University of Life Sciences (NMBU), Master thesis. Department of International Environment and Development Studies (Noragric).

Muchunku, C., Ulsrud, K., Winther, T., Palit, D., Kirubi, G., Saini, A., Mauta, W. & Rohracher, H. (2014). The Solar Energy Center – An Approach to Village Scale Power Supply: Report from the Solar Transitions pilot project in Kenya.

Murphy, J. T. (2001). Making the energy transition in rural East Africa: Is leapfrogging an alternative. *Technological Forecasting and Social Change*, 68 (1): 173-193.

NESH. (2006). *Forskningsetiske retningslinjer for samfunnsvitenskap, humaniora, juss og teologi*. Oslo: Forskningsetiske komiteer.

Nevens, F., Frantzeskaki, N., Gorissen, L. & Loorbach, D. (2013). Urban Transition Labs: co-creating transformative action for sustainable cities. *Journal of Cleaner Production*, 50 (1): 111-122.

Newell, P., Phillips, J., Pueyo, A., Kirumba, E., Ozor, N. & Urama, K. (2014). The Political Economy of Low Carbon Energy in Kenya. *IDS Working Papers*, 2014 (445): 1-38.

Nouni, M. R., Mullick, S. C. & Kandpal, T. C. (2009). Providing electricity access to remote areas in india: Niche areas for decentralized electricity supply. *Renewable Energy*, 34 (1): 430-434.

Olsen, O. E. & Lindøe, P. (2004). Trailing research based evaluation; phases and roles. *Evaluation and program planning* (27): 371-380.

Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and Tanzania. *Energy Policy*, 56 (1): 407-417.

Ornetzeder, M. & Rohracher, H. (2005). Social Learning, Innovation and Sustainable technology. In Filho, W. L. (ed.) *Handbook of sustainability research*, pp. 147-175. Frankfurt: Peter Lang.

Ostrom, E. (2004). Collective Action and Property Rights for Sustainable Development. Understanding Collective Action. *Focus II, Brief 2 of 16 (2004)*: International Food Policy Research Institute.

Palit, D. & Hazarika, N. (2002). *Renewable Energy for Rural Development*. Performance and Impact of the Solar Photovoltaic Devices Disseminated for Village Electrification in North East India. Dhaka, Bangladesh. , .

Palit, D. & Chaurey, A. (2011). Off-grid rural electrification experiences from South Asia: Status and best practices. *Energy for Sustainable Development*, 15 (3): 266-276.

Palit, D. (2013). Solar energy programs for rural electrification: Experiences and lessons from South Asia. *Energy for Sustainable Development*, 17 (3): 270-279.

Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods*. 3 ed. London, United Kingdom: Sage Publications.

Peet, M. (1998). *Modern Geographical Thought*: Blackwell Publishers.

Perez, C. (2002). *Technological revolutions and financial capital: the dynamics of bubbles and golden ages*. Cheltenham: Edward Elgar.

Perkins, R. (2003). Environmental leapfrogging in developing countries: A critical assessment and reconstruction. *Natural Resources Forum*, 27 (1): 177-188.

Practical Action. (2014). Poor people's energy outlook 2014: Key messages on energy for poverty alleviation. Rugby, United Kingdom: Practical Action Publishing.

Ramakumar, R., Abouzahr, I., Krishnan, K. & Ashenayi, K. (1995). Design scenarios for integrated renewable energy systems. *Energy Conversion, IEEE Transactions on*, 10 (4): 736-746.

Raven, R. (2007). Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls. *Energy Policy*, 35 (4): 2390-2400.

Raven, R. P. J. M. (2005). *Strategic Niche Management for Biomass: A Comparative Study on the Experimental Introduction of Bioenergy Technologies in the Netherlands and Denmark*. Eindhoven Centre for Innovation Studies: VDM Verlag.

Raven, R. P. J. M., Heiskanen, E., Lovio, R., Hodson, M. & Brohmann, B. (2008). The Contribution of Local Experiments and Negotiation Processes to Field-Level Learning in Emerging (Niche) Technologies: Meta-Analysis of 27 New Energy Projects in Europe. *Bulletin of Science, Technology & Society*, 28 (6): 464-477.

Reason, P. & Bradbury, H. (2008). *The SAGE Handbook of Action Research. Participative Inquiry and Practice*. 2 ed. London, United Kingdom: Sage Publications.

Recha, J., Kinyangi, J. & Omondi, H. (2012). Climate related risk and opportunities for agricultural adaptation and mitigation in semi-arid eastern Kenya.

Reddy, N. M. & Zhao, L. (1990). International technology transfer: A review. *Research Policy*, 19 (4): 285-307.

Republic of Kenya. (2010). *The 2009 Kenya Housing and Population Census*. Kenya National Bureau of Statistics, G. o. K. Nairobi, Kenya.

Republic of Kenya. (2012a). *Master plan for the conservation and sustainable management of water catchment areas in Kenya*. Ministry of Environment and Mineral Resources. Nairobi, Kenya.

Republic of Kenya. (2012b). *'Releasing Our Full Potential' - Sessional Paper No. 8 of 2012 on National Policy for the Sustainable Development of Northern Kenya and other Arid Lands*. Ministry of State for Development of Northern Kenya and Other Arid Lands. Nairobi, Kenya.

Rip, A. & Kemp, R. (1998). Technological Change. In Rayner, S. & Malone, E. L. (eds) vol. 2 *Human choice and climate change*, pp. 327-399. Columbus, Ohio: Battelle Press.

Rohracher, H. (2001). Managing the Technological Transition to Sustainable Construction of Buildings: A Socio-Technical Perspective. *Technology Analysis & Strategic Management*, 13 (1): 137-150.

Rohracher, H. (2002). A Sociotechnical Mapping of Domestic Biomass Heating Systems in Austria. *Bulletin of Science, Technology & Society*, 22 (6): 474-483.

Rohracher, H. (2003). The Role of Users in the Social Shaping of Environmental Technologies. *Innovation: The European Journal of Social Science Research*, 16 (2): 177-192.

Rohracher, H. (2006). *The Mutual Shaping of Design and Use. Innovations for Sustainable Buildings as a Process of Social Learning.* München, Germany: Profil Verlag.

Rohracher, H. (2009). Intermediaries and the governance of choice: the case of green electricity labelling. *Environment and Planning A*, 41 (1): 2014-2028.

Román, M., Linnér, B.-O. & Mickwitz, P. (2012). Development policies as a vehicle for addressing climate change. *Climate and Development*, 4 (3): 251-260.

Romijn, H., Raven, R. & de Visser, I. (2010). Biomass energy experiments in rural India: Insights from learning-based development approaches and lessons for Strategic Niche Management. *Environmental Science & Policy*, 13 (4): 326-338.

Romijn, H. A. & Caniëls, M. C. J. (2011). Pathways of technological change in developing countries: Review and new agenda. *Development Policy Review*, 29 (3): 359-380.

Russell, S. & Williams, R. (2002). Social shaping of technology: Frameworks, findings and implications for policy with glossary of social shaping concepts. In Williams, R. & Sørensen, K. H. (eds) *Shaping technology, guiding policy: concepts, spaces and tools*. Cheltenham: Edward Elgar.

Schot, J., Hoogma, R. & Elzen, B. (1994). Strategies for shifting technological systems: The case of the automobile system. *Futures*, 26 (10): 1060-1076.

Schot, J. & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20 (5): 537-554.

Seyfang, G. & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, 16 (4): 584-603.

Seyfang, G. & Haxeltine, A. (2012). Growing grassroots innovations: exploring the role of community-based initiatives in governing sustainable energy transitions. *Environment and Planning C: Government and Policy*, 30 (3): 381-400.

Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M. & Smith, A. (2013). A grassroots sustainable energy niche? Reflections from community energy case studies. *S3 Working Paper 2013-21*. UK: University of East Anglia.

Shove, E. & Walker, G. (2010). Governing transitions in the sustainability of everyday life. *Research Policy*, 39 (4): 471-476.

Shrank, S. (2008). Another Look at Renewables on India's Sagar Island. *Working Paper #77, July 2008. Program on Energy and Sustainable Development (PESD), Stanford.*

Shrimali, G. & Rohra, S. (2012). India's solar mission: A review. *Renewable and Sustainable Energy Reviews*, 16 (1): 6317-6332.

Silverman, D. (2011). *Interpreting qualitative data*. 4th ed. London: Sage.

Smith, A., Stirling, A. & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, 34 (10): 1491-1510.
Smith, A. (2007). Translating Sustainabilities between Green Niches and Socio-Technical Regimes. *Technology Analysis & Strategic Management*, 19 (4): 427-450.
Smith, A. & Stirling, A. (2007). Moving Outside or Inside? Objectification and Reflexivity in the Governance of Socio-Technical Systems. *Journal of Environmental Policy & Planning*, 9 (3-4): 351-373.
Smith, A. & Stirling, A. (2010). The Politics of Social-ecological Recilience and Sustainable Socio-technical transitions. *Ecology and Society*, 15 (1).
Smith, A. (2012). Civil Society in Sustainable Energy Transitions. In Verbong, G. & Loorbach, D. (eds) Routledge Studies in Sustainability Transitions vol. 4 *Governing the Energy Transitions*, pp. 180-202. New York, U.S, London, U.K: Routledge
Smith, A. & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, 41 (6): 1025-1036.
Smith, A., Kern, F., Raven, R. & Verhees, B. (2014). Spaces for sustainable innovation: Solar photovoltaic electricity in the UK. *Technological Forecasting and Social Change*, 81: 115-130.
Soete, L. (1985). International diffusion of technology, industrial development and technological leapfrogging. *World Development*, 13 (3): 409-422.
Soete, L. (2009). International research partnerships on the move. In Molenaar, H., Box, L. & Engelhard, R. (eds) *Knowledge on the move. Emerging agendas for development-oriented research*, pp. 33-48. Leiden, NL: International Development Publications.
Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science*, 1: 1-29.
Späth, P. & Rohracher, H. (2012). Local Demonstrations for Global Transitions—Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability. *European Planning Studies*, 20 (3): 461-479.
Standal, K. (2008). *Giving light and hope in rural Afghanistan. The impact of Norwegian Church Aid's barefoot approach on women beneficaries*. Oslo: University of Oslo, Department of sociology and human geography.
Stirling, A. (2008). Science, precaution, and the politics of technological risk: converging implications in evolutionary and social scientific perspectives. *Annals of the New York Academy of Sciences*, 1128: 95-110.
Stirling, A. (2009). Direction, Distribution and Diversity! Pluralising Progress in Innovation, Sustainability and Development. *STEPS Working Paper 32*. Brighton, UK: STEPS Centre, University of Sussex.
Stokke, M. K. (2014). *Scaling up by cutting down? - A study of a solar power pilot project and the attempts of going from pilot to scale in rural Kenya*. Oslo, Norway: University of Oslo, Masters Thesis. Centre for Technology, Innovation and Culture, Faculty of Social Sciences.
Swantz, M. L. (2008). Participatory action research as practice. In Reason, P. & Bradbury, H. (eds) *Action research*. London: Sage Publications Ltd.
Sæther, B. (2007). From Researching Regions at a Distance to Participatory Network Building: Integrating Action Research and Economic Geography. *Systemic Practice and Action Research*, 20 (1): 15-25.
Sæther, B. (2010). Deltakelse og forskernes rolle i utvikling av et bedriftsnettverk. In Album, D., Hansen, M. N. & Widerberg, K. (eds) *Metodene våre. Eksempler fra samfunnsvitenskapelig forskning*, pp. 205-2017. Oslo, Norway: Universitetsforlaget.
Sørensen, K. H. (2013). Beyond Innovation: Towards an extended framework for analysing technology policy. *Nordic Journal of Science and Technology Studies*, 1 (1).
TERI. (2009). Solar Transitions: A background Paper on Experience of Solar Power Plant in Sunderbans, India. Draft report. Prepared for University of Oslo, Norway. *The Energy and Resources Institute*, Project report No. 2009BL03.

Thagaard, T. (2010). *Systematikk og innlevelse - en innføring i kvalitativ metode*. 3 ed. Bergen, Norway: Fagbokforlaget.
Ulsrud, K., Sygna, L. & O'Brien, K. (2008). *More than rain: Identifying sustainable pathways for climate adaption and poverty reduction*. Oslo: Utviklingsfondet.
Ulsrud, K., Winther, T., Palit, D., Rohracher, H. & Sandgren, J. (2011). The Solar Transitions research on solar mini-grids in India: Learning from local cases of innovative socio-technical systems. *Energy for Sustainable Development*, 15 (3): 293-303.
Ulsrud, K., Winther, T., Palit, D. & Rohracher, H. (2015). Village-level solar power in Africa: Accelerating access to electricity services through a socio-technical design in Kenya. *Energy Research & Social Science*, 5: 34-44.
Unruh, G. C. (2002). Escaping carbon lock-in. *Energy Policy*, 30 (4): 317-325.
Urmee, T. & Harries, D. (2009). A survey of solar PV program implementers in Asia and the Pacific regions. *Energy for Sustainable Development*, 13 (1): 24-32.
Verbong, G. & Geels, F. (2007). The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960-2004). *Energy Policy*, 35 (2): 1025-1037.
Verbong, G., Christiaens, W., Raven, R. & Balkema, A. (2010). Strategic Niche Management in an unstable regime: Biomass gasification in India. *Environmental Science & Policy*, 13 (4): 272-281.
Verhees, B., Raven, R., Veraart, F., Smith, A. & Kern, F. (2013). The development of solar PV in The Netherlands: A case of survival in unfriendly contexts. *Renewable and Sustainable Energy Reviews*, 19 (1): 275-289.
Vognild, R. (2011). *Renewable energy and climate adaptation: Exploring the role of solar power supply for climate adaptation on Moushuni Island, India*. Norway: University of Oslo, Department of Sociology and Human Geography.
Walker, G., Hunter, S., Devine-Wright, P., Evans, B. & Fay, H. (2007). Harnessing Community Energies: Explaining and Evaluating Community-Based Localism in Renewable Energy Policy in the UK. *Global Environmental Politics*, 7 (2): 64-82.
Walker, G. & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy*, 36 (2): 497-500.
Wieczorek, A. J. & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and Public Policy*, 39 (1): 74-87.
Wilhite, H. (2008). New thinking on the agentive relationship between end-use technologies and energy-using practices. *Energy Efficiency*, 1 (2): 121-130.
Wilkins, G. (2002). *Technology transfer for renewable energy: overcoming barriers in developing countries*. London: Earthscan.
Williams, R. & Sørensen, K. H. (eds). (2002). *Shaping technology, guiding policy: concepts, spaces and tools*. Cheltenham: Edward Elgar.
Winther, T. (2005). *Current styles: introducing electricity in a Zanzibari village*. Oslo, Norway: University of Oslo, Centre for Development and the Environment.
Winther, T. (2008). *The impact of electricity: development, desires and dilemmas*. New York: Berghahn Books.
Winther, T. (2012). Electricity theft as a relational issue: A comparative look at Zanzibar, Tanzania, and the Sunderban Islands, India. *Energy for Sustainable Development*, 16 (1): 111-119.
Winther, T. (2014). The introduction of electricity in the Sundarban Islands: Conserving or transforming gender relations? In Nielsen, K. B. & Waldrop, A. K. (eds) *Women, gender and everyday social transformation in India*, pp. 47 – 61. London, UK: Anthem Press.
Wong, S. (2012). Overcoming obstacles against effective solar lighting interventions in South Asia. *Energy Policy*, 40: 110-120.

World Bank. (2008). The welfare impact of rural electrification: a reassessment of the costs and benefits. An IED impact evaluation. Washington DC, USA: The World Bank.

World Bank & IEA. (2013). Global Tracking Framework. Sustainable Energy for All: World Bank and International Energy Agency.

Yadoo, A. & Cruickshank, H. (2012). The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini-grids with case studies in Nepal, Peru and Kenya. *Energy Policy*, 42 (0): 591-602.

Yin, R. K. (2013). *Case Study Research: Design and Methods*. London, United Kingdom: Sage Publications.